Journal
of
The Franklin Institute
Devoted to Science and the Mechanic Arts

Vol. 190 OCTOBER, 1920 No. 4

OPTICAL GLASS AND ITS FUTURE AS AN AMERICAN INDUSTRY.*

BY

ARTHUR L. DAY, Ph.D., Sc.D.

Director, Geophysical Laboratory, Carnegie Institution of Washington, D. C.
(In charge of Optical Glass Production, War Industries Board.)

THE problem of preparation for a war in which the scope of its technique and the wealth of the available resources are both practically unlimited, will hardly be comprehended at a glance by anyone, whatever his previous training may have been. It is an absolutely baffling task. By way of illustration consider artillery fire, which during the Civil War was practically always point blank; that is, aim was taken directly at a nearby object, either in plain view or partially concealed by smoke. The effective range was rarely more than 3000 yards, and the pieces were pointed by instinct or by sighting along the barrel, but none of the present day equipment for ascertaining the range of very distant objects was then thought of. Few of the guns were rifled at all, high-power explosives had not been discovered, muzzle loading by hand was nearly universal, and except for the old-fashioned siege mortars high angle fire was not attempted.

* Presented at a joint meeting of the Section of Physics and Chemistry and the Philadelphia Section, American Chemical Society, held Thursday, March 25, 1920.

[Note.—The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the JOURNAL.]

COPYRIGHT, 1920, by THE FRANKLIN INSTITUTE.

The artillery practice of the present war included, as will be recalled, the remarkable achievement of bombarding the city of Paris from a distance of about 72 miles. Moreover, in the regular daily artillery battles naval guns were frequently concentrated to "cover" an opposing battery which might be distant ten miles or more, perhaps be completely concealed by intervening hills or trees, and which sometimes occupied no more space than an area 50 or 60 yards square. Moreover, it is told of this kind of fire that it frequently was so successfully concentrated that such batteries were completely wiped out by a single avalanche of high-explosive shell.

Artillery practice of this character necessarily requires instruments of the highest precision and of complicated mechanism which are capable of adjustment for nearly all variations of service conditions including allowance for atmospheric changes high above the earth. It is thus easy to see that not only must a high degree of mechanical skill be worked out in advance to provide this technique, but the glass of which the optical parts of the instruments are made must be of the highest perfection in order not to vitiate this technique when developed.

The problem of supplying optical glass in adequate quantity and perfection was therefore one of the most serious problems confronting the ordnance departments from the first moment when our entry into the war was seriously considered. There is no possibility of accurate fire control without optical glass.

At the end of March, 1917, a committee was appointed from the Naval Consulting Board to inquire into the supply of optical glass of quality suitable for fire control instruments for the use of the military and naval forces of the United States in the event of our participation in the war. This is the first action of record, so far as I am aware, to obtain a supply of this absolutely indispensable material.

The situation may well have been deemed precarious, for the reason that at that time the European war had been going on for nearly three years and the available supply of imported glass in the hands of American manufacturers had become seriously depleted in filling contracts with various allied powers. In point of fact, substantially all of the optical glass of the first quality on hand in this country in 1914 had been manufactured and exported in finished instruments and none of the allied governments had been

willing, after the outbreak of the war, to allow such an indispensable material to be exported in quantity.

From the point of view of proper fire control instruments therefore the moment chosen for the entry of the United States into the conflict was perhaps the worst that could have been selected.

The Committee of the Naval Board, which had been commissioned to investigate the optical glass resources of the country, discovered and reported substantially this situation. In his report the chairman (Mr. Baekeland) outlined the conditions which he had found and recommended to the consideration of the Navy Department that the whole matter be placed in the hands of the Bureau of Standards, which, in his opinion, was in the best position to take up the question intelligently and to propose an effective solution.

The next active step to provide a supply of optical glass was taken by the National Research Council in April, 1917, a few days after our declaration of war. The speaker was delegated by this body to make a personal canvass of the possible resources of the country, visiting all who were known to have knowledge of the manufacture of optical glass, and to report with recommendations.

This inquiry developed the fact, contrary to the news items on the subject which had begun to appear rather frequently in the papers, that optical glass in small quantities had been made in this country long before the year 1917. It is to the credit of the elder Macbeth, of the Macbeth-Evans Company, that the first attempt to manufacture in this country glass of high optical quality was undertaken in the early nineties and a number of creditable lenses, some of considerable size, stand as monuments to the success of this effort. Nevertheless the undertaking was financially unprofitable and the enterprise was abandoned after a short time. In 1912 the Bausch & Lomb Company, who were the largest manufacturers of instruments of precision in the United States, determined to control their own glass supply, and with the aid of a Belgian expert began making optical glass in their plant at Rochester. A factory fire soon afterward consumed the building and some delay occurred, but in 1914 very creditable samples of optical glass were produced in this plant. Because of the demands of the great war this industry flourished and the initial small pot furnace was soon replaced by other larger ones, and at the period

when this record begins (March, 1917) this company was engaged upon large contracts for field glasses for the Canadian Government and for the British Field Service, in which the glass used was in part, at least, of American manufacture. The total output of this plant which might be considered available for American use at this critical moment was perhaps as much as 2000 pounds per month, a quantity sufficient in their expert hands for a considerable number of optical instruments.

It is also a matter of record in the annual report of the Director of the Bureau of Standards, dated June 30, 1915, that the possibility of our being drawn into the European conflict had been foreseen and the consequent possibility of our being suddenly called upon to provide an independent supply of glass of optical quality had been considered there. Some time during this year a small furnace was erected at the Bureau Laboratory in Pittsburgh, in which a number of pioneer essays in this field were attempted. Chief among these was the effort to provide a suitable container or melting pot in which the glass could be melted without contamination. The clay which had been used in glass melting for most commercial purposes in this country before the war was also of foreign origin, and when this supply was cut off American pot makers found themselves without competent knowledge of American clays which might be substituted for the imported clay. The records of the United States Geological Survey show that clays are found in this country in greater quantity and variety than in any of the European countries, but in the absence of adequate knowledge of how to use them, the chance of developing suitable melting pots from American clays was not encouraging. The Bureau of Standards made a serious effort in the years 1915 and 1916 to meet this situation, but it happens that a glass-melting pot of suitable size for this purpose requires for making and burning a period of about four months, so that the development of the necessary experience proceeded slowly.

At the time when our situation was most critical (March, 1917) the experimental work of the Bureau of Standards had not proceeded far enough to be of great assistance. Their experimental work with pots was not finished and only one type of optical glass (a borosilicate crown) had been successfully made.

During this period also, and more or less in collaboration with the Bureau of Standards, Mr. Carl Keuffel, of the firm of Keuffel

& Esser, had erected at the works of his company in Hoboken a small furnace in which also a successful attempt had been made to produce this type of glass, using pots of his own design and manufacture.

In the year 1916 the Spencer Lens Company, of Buffalo, erected a small plant at Hamburg, N. Y., and also began the manufacture of optical glass with a view to replace the foreign sources of supply already closed by the war. The capacity of the plant, as operated during the late months of 1916 and early 1917, was not above 200 pounds per month, and actual production was considerably less than this, being uncertain both in quantity and quality.

The chemist of the Hazel-Atlas Company, Washington, Pa., Mr. Duval, who was also reputed to have been a successful maker of optical glass in Europe in earlier years, had already set up an extemporized furnace in this country and had melted a single pot of glass of such quality as to win favorable consideration from a firm as exacting in its requirements as the John A. Brashear Company, of Pittsburgh.

It also appeared that in 1915 the Pittsburgh Plate Glass Company, at its plant in Charleroi, Pa., had begun making considerable quantities of spectacle glass and other high grade special glasses not particularly intended for optical instruments, but nevertheless of excellent commercial quality. Incidentally, this plant proved to be the largest in the United States which might be deemed immediately available for the production of optical glass, and if it should be possible to improve the quality up to the standards of the army and navy, might contribute much to relieve the immediate need.

This then was the situation at the period of our entry into the war. One firm was regularly producing glass of fair optical quality at the rate of perhaps 2000 pounds per month. There was another plant of much larger capacity which might be deemed available, but which had never produced glass of strictly optical quality, and four others, including the Bureau of Standards Laboratory, all of which were very small and still in the experimental stage.

The estimated requirements of the army and navy, as forecast by the General Munitions Board in the month of April, 1917, amounted roughly to 2000 pounds per day.

There were very earnest conferences in the National Research Council following upon this discovery before a course of action was determined upon. Finally it was decided to ask the President of the Carnegie Institution of Washington to allow the resources of the Geophysical Laboratory, both in men and apparatus, to be applied to this overwhelming task. The obvious reason for this was, not that optical glass had ever been made there, but that at the Geophysical Laboratory there was available a larger and more experienced group of silicate chemists than perhaps could be found elsewhere. This permission was granted by authority of the Executive Committee of the Institution upon the 18th of April, 1917, twelve days after the declaration of war. From that time until the conclusion of the armistice on November 11, 1918, practically all of the resources of the Laboratory were placed at the disposal of the Government without expense to it either direct or indirect.

Upon the assumption by the Laboratory of this responsibility several steps were taken immediately:

(1) To initiate a canvass through the United States Geological Survey to discover a source of supply of sand of the highest possible quality.

(2) By a canvass of chemical manufacturing establishments to discover a source of potash with which to supply this indispensable ingredient which hitherto had been regularly imported from abroad.

(3) To delegate a group of men to make analyses of typical glasses of foreign manufacture with a view to determining the ingredients used and the relation between chemical composition and optical properties.

(4) To delegate a group of men to aid the Bausch & Lomb Company in the development of new varieties of glasses which might be needed and in securing greater perfection of quality in those already made.

(5) To canvass the manufacturers of melting pots throughout the country and to make a careful examination of the iron content of these pots with a view to guarding against contamination of the glass melt by iron, for it is a well known fact that of all the substances regularly present in optical glasses, iron is the one which most diminishes transparency and is also the one most difficult to eliminate.

The results of this canvass will be adverted to in a moment.

After the organization of the General Munitions Board, of which Mr. F. A. Scott, of Cleveland, was the first chairman, the question of an optical glass supply was felt to be very acute. A number of sessions were held and eventually a committee was appointed (May, 1917) to give continuous attention to the task. The committee consisted of Prof. Millikan, of the University of Chicago, chairman; Mr. Stratton, of the Bureau of Standards, and the present speaker.

After the canvass of the situation, which has been outlined above, it appeared clear that all of the sources of optical glass available in May, 1917, could together produce only about half of the quantity required, assuming that all of the glass produced was of quality suitable for war equipment. At that time the Bausch & Lomb Company alone were producing glass of such quality. Moreover, it was estimated that they might, by extending their plant, carry approximately one-half of the war load. To maintain the other half there appeared to be but a single course open, namely, in some manner to make the Charleroi plant of the Pittsburgh Plate Glass Company available and to place someone in charge of it who should have sufficient knowledge of the requirements and technique to raise the quality of glass produced there to the standard which the Government required and which they had not hitherto attained alone.

After several conferences a plan was agreed upon whereby the Pittsburgh Company should undertake to perfect their glass under the direction of the Bureau of Standards Laboratory, located nearby. It appeared to the committee that such an arrangement might work out advantageously, for the chemists of the Geophysical Laboratory were already in charge at Rochester and a gentle rivalry between the two institutions might prove an incentive to each, of a kind which might bring results more rapidly than without such an arrangement. In addition to this the Bureau of Standards had received through the Naval Board the sum of $75,000 for the extension of its own plant in Pittsburgh, and it was thought that with this organization thus strengthened and given control of the facilities at Charleroi, the other half of the war production would be attained.

In practice there was some disappointment in carrying out this plan. At the close of the year 1917 the Bausch & Lomb Company

was producing in Rochester at the rate of about 40,000 pounds per month, while the Pittsburgh Plate Glass Company had not been able in the eight months interval to provide any glass which would pass the Government inspection standards.

At that time Mr. Raymond, General Manager of the Pittsburgh Company, decided that the basis upon which they were producing was not destined to prove successful, and application was made to the Geophysical Laboratory to divide its force at Rochester and to permit a number of the chemists who had been successful there to take up the Pittsburgh problem. This was practically laying the entire load upon the Geophysical Laboratory, because only one month previous (December 4, 1917) the Laboratory had taken the responsibility for production in the third of the optical plants, that of the Spencer Lens Company, of Buffalo, and every man of its force was occupied to the limit of his capacity. Indeed the requirements at that time were so pressing that there was need to strain the situation to the breaking point if necessary in order to secure the maximum producing capacity out of every available furnace. Dr. J. C. Hostetter, of the Geophysical Laboratory staff at Rochester, with three associates, Drs. Adams, Williamson, and Mr. Roberts, from the Washington Laboratory, and Dr. Taylor, of the Bureau of Standards Laboratory, by invitation, undertook this most difficult problem, beginning on January 1, 1918. Dr. Bowen was soon after detached from the Spencer Lens Company plant and added to this group.

Speaking at this distance of the situation which then confronted us, it is perhaps not unfair to say that we would have done more wisely to have further enlarged the plant at Buffalo or at Rochester, or both, to the size required to produce the glass needed rather than to attempt the immense problem which the Charleroi plant presented. Sixteen furnaces were available which had already been used for glass-making, and others which might be turned to the task should circumstances require, but all of the furnaces were of an old type without regeneration and without means for controlling the temperature in individual furnaces within 100 degrees centigrade, whereas it was already established by our experience at Rochester that a control as close as 5 degrees must be continuously maintained in each individual furnace to insure success.

The Pittsburgh Company was liberal in its plans and the Gov-

ernment placed a large contract, amounting to 100,000 pounds, with the company in order to afford an incentive to press forward as rapidly as possible the improvements which were needed. Certain specified improvements were even authorized to be charged against cost of the glass delivered. Nevertheless production lagged, and it was not until the following July that the output contemplated in the original plan was attained. In the intervening months the average production had been from 3000 to 6000 pounds per month, which afforded a modest contribution in addition to the production elsewhere, but it amounted to scarcely 10 per cent. of the production of the Rochester plant throughout the spring months.

In contrast to this situation, and to the difficulties encountered at Charleroi, it is interesting to consider the progress of the small plant of the Spencer Lens Company, at Buffalo, in the same interval. This plant was new and though small was capable of competent control. Accordingly production up to the existing capacity began in the month of December and continued uninterruptedly thereafter until June, 1918, when it was approximately doubled by additional building, and in August when it was doubled again. Two of the members of the staff of the Geophysical Laboratory (Drs. Fenner and Bowen) went from the Rochester plant to start this furnace, and of the first 22 pots which were put through after their arrival not one failed.

In the Spring of 1918 the General Munitions Board was replaced by the War Industries Board, a considerably larger and more diversified body, but, like its predecessor, advisory rather than authoritative in character. Nevertheless by agreement of the Purchasing Departments of the various Ordnance Bureaus authority was placed in its hands to exercise a certain amount of supervision of contracts with a view to increasing the effectiveness of production by regulating the size of contract and time of delivery to the producing capacity of the manufacturer, and by aiding him in various ways. In particular, with respect to optical glass, the reorganization terminated the existence of the Optical Glass Committee of the General Munitions Board, and in its place provided a certain amount of direct authority over manufacturing processes. For example, in the contract for 100,000 pounds of optical glass issued to the Pittsburgh Plate Glass Company early in 1918, the specifications of the glasses and the con-

ditions of inspection were written into the contract, together with the requirement that all of the glass to be delivered under the contract should be produced under the direct supervision of the Director of the Geophysical Laboratory, who was designated "In Charge of Optical Glass Production, War Industries Board." This arrangement had the effect of giving to the representatives of the Laboratory in the various plants over which they exercised control, absolute authority to prescribe the raw materials which should be used and the details of all the processes through which these materials were to be passed up to the time of the inspection of the finished product, which was done by authorized representatives of the Ordnance Department of the branch of the service to which the glass was consigned. The Geophysical Laboratory at no time exercised any authoritative control over the inspection standards or the manner of applying them.

This organization and procedure was common to all of the three large plants until the conclusion of the armistice in November, 1918, and except for a small quantity of glass manufactured in the Laboratory of the Bureau of Standards at Pittsburgh, and a still smaller quantity made by the Keuffel & Esser Company, covered all of the glass produced for war uses during this year.

Leaving now the Washington organization and its relation to the manufacturing plants, some account may properly be given of the steps taken, (1) to raise the quality of the glass to meet the inspection standards set by the Government, (2) to increase production to the magnitude required by the war needs.

Although the phrase "optical glass" has become familiar through notices printed in the papers from time to time during the progress of the war, in point of fact but little has been printed of the qualities which serve to distinguish optical glass from other glasses. In general it may be said that optical glass is the highest type of clear glass known in the art. A single illustration may serve to explain my meaning. Ordinary spectacle glass in its conventional use appears clear and white, but if it is held so as to permit looking through the glass edgewise considerable color may usually be detected, so that it might occur to one as doubtful whether it would be possible to see clearly through the same glass if the thickness were represented by the width of the glasses rather than by their shortest dimension. For optical purposes, notably in the case of prisms used in range finders and periscopes,

very much greater thicknesses than this are common, and a glass for such a purpose must be optically perfect throughout its thickness, which may often reach four or five inches.

The qualities assigned for test in establishing standards of inspection for optical glass, very briefly, are these:

(1) Homogeneity, by which is meant uniformity in chemical composition, freedom from striation, bubbles, inclusions and crystallization.

(2) A constant refractive index and a constant dispersion ratio throughout.

(3) Freedom from color.

(4) High transparency.

(5) Both physical and chemical stability, by which is meant durability under exposure to the weather, chemical fumes, etc., as well as toughness and hardness for protection against misuse.

(6) Physical homogeneity, by which is meant freedom from strains or internal stresses caused by uneven cooling of the molten glass.

To produce glasses with these qualities the first obvious requirement is high chemical purity in all the ingredients of the glass itself and the second either an insoluble pot in which to melt it, or one in which the ingredients entering the glass from the pot shall not impair the development of the above qualities.

The search for such materials, which was immediately instituted by the Geophysical Laboratory when it was first authorized to take up the optical glass problem, yielded the following results:

After a search of the sand quarries from the State of Washington to Florida, including more than forty-five different localities, a sand was finally located at Rockwood, Mich., of which the analysis indicated greater purity than that from any known source of supply, even including in the comparison the wonderful sand of Fontainebleau (France) which has been used both in France and England for artistic glassware for a hundred years.

A number of sources of potash were canvassed, in the course of which much disappointment was experienced. Not only were the efforts, which were first put forth in this country to make potassium carbonate, less successful than might be wished, but the cost of manufacture was almost prohibitive. European potash was laid down in New York before the war at six cents per pound, while the major portion of the American-made potassium car-

bonate used in the manufacture of optical glass, cost the Government in the neighborhood of $1.00 per pound. This fact is of some importance as an indication of the outlook in store for an independent optical glass industry in this country now that the war has closed.

It is to the credit of the Armour Company, of Chicago, that the first potassium carbonate of adequate purity was produced in this country. Subsequently it was found possible to substitute the nitrate for the carbonate, either in part or altogether, and so to obtain a salt which was equally good and much more generally available. But even so, the necessary provision for potash in some of the glasses remained to haunt us throughout our entire experience of glass manufacture without reaching an altogether satisfactory final solution. Sulphur and chlorine, one or both, were very often found, and a small percentage of either is usually sufficient to give a milky cast to the finished product.

In view of the long period of time needed (about four months) to manufacture, to dry, and to burn the pots which must contain the glass during melting, to which allusion has been made above, this investigation also was never quite satisfactorily concluded. In the beginning it was of course necessary to purchase in the open market such pots as were then available. These had not been made with a view to their use in the manufacture of glass of high purity, and in general were found to contain about one hundred times as much iron per cubic centimeter as could safely be permitted in the finished glass (2.0 per cent., compared with 0.02 per cent.). It is therefore a matter of easy calculation to show that, however pure may be the sand, potash, lead, and other ingredients required for a particular glass, there was more than an even chance that enough of the contact surface of the pot would be dissolved in the mixture to contaminate the contents of the glass beyond the limits of tolerance. Between the iron, which diminishes transparency, and the sulphur, which even in very small quantities causes milkiness, many a pot of promising glass found its way into the Genessee River during the early days at Rochester without in any way aiding our troops at the front.

Nevertheless our pot makers, with a single exception, put forth a splendid effort to meet the situation by conducting experiments simultaneously in several plants, and it proved possible within four or five months to obtain containers in which the raw ma-

terial was sufficiently free from contaminating elements so that glasses of a purity comparable with the best European glasses could be obtained. This conclusion was aided considerably by the discovery that if the pot was first burned in a furnace at a temperature considerably higher than any which would be required for melting the glass, burned even until the side walls showed signs of sagging and the surface became more or less glazed, then the solution of pot material in the glass was very greatly diminished. By the use of this process, even more perhaps than through more intelligent selection of clays, it became possible to melt nearly all of the glasses with a minimum of contamination from the pots.

Of course in the manufacture of optical glass, as opposed to other branches of the glass industry, a pot is used but once, which makes it very much easier to provide means for avoiding or limiting the solution of pot material in the glass. An absolutely insoluble pot is unknown for the reason that all of the oxides which enter into glass composition, as well as the refractory oxides used about the furnace, are mutually soluble.

Toward the close of the war period the porcelain type of pot developed by Dr. Bleininger, of the Bureau of Standards, was very successfully used with the glasses made in the Bureau Laboratory, but was not successfully manufactured by other pot makers in time to be of service. This pot possessed a smaller iron content and in general a lower solubility than any pot prepared for optical glass during the war period, but unfortunately could not be made generally available.

From the Laboratory point of view the most interesting problem was presented in the initial studies at the Bausch & Lomb plant, (1) of processes through which to obtain constant composition, and (2) to establish a definite relation between chemical composition and the optical constants prescribed by the requirements of the service.

In this connection it should be borne in mind that a glass solution is never in equilibrium, but is constantly changing in composition. Lead oxide and the alkalies are somewhat volatile, while the containing vessel continually contributes alumina, silica, and usually iron. It is therefore necessary for the student of glass melting who wishes above everything to attain to a prescribed chemical composition, to establish precise data upon the

rate of evaporation at particular temperatures of those ingredients which pass out of the furnace and, at least approximately, the rate of solution of the pot in the glass. Knowing these quantities and the time of exposure necessary to mature a glass which is free from stones (that is, completely dissolved) and free from tiny bubbles, of which there is constant danger with every shift in the temperature, it is possible to produce successful pots of glass of accurately uniform composition and so to define and to reproduce definite optical constants.

The general relation between composition and optical constants is obviously the main issue in optical glass manufacture, and is therefore very conspicuous by its almost complete absence from the literature of the subject. Much of the optical glass technique has been enveloped in profound secrecy in all the three countries where it has been mainly produced, and although more or less freedom has been permitted in the publication of technical details of temperature, of stirring, and even of chemical composition, the manner of varying optical constants in any desired way through changes in composition has remained a trade secret up to the present time.

In this connection it is perhaps interesting to remark parenthetically that at the time when the French Liaison Commission visited this country after our entry into the war, to aid us with their experience in the production of war material, it was not permitted to divulge any details regarding the manufacture of optical glass upon the ground that the integrity of the existing glass monopoly in France had always been respected by the Government and must be so still, in spite of the war pressure. England adopted a similar attitude, and so in this one branch of the service the United States was left to proceed unaided to endeavor as best it might to reproduce within the period of a few months all of the experience which had been attained in optical glass manufacture since the days of Abbe and Schott in the early eighties.

It became necessary therefore to proceed much as a scientific man is accustomed to proceed in other unknown fields, by varying quantitatively each ingredient present and plotting the results in curves through which the effect of each ingredient on the optical constants of the resulting glass might be determined. This was done systematically and very successfully, so that within a period of three months from the beginning of our efforts it became pos-

sible for Dr. Fred E. Wright, who was in charge of the work at Rochester, to write formulæ for any of the typical glasses required for war service without advice from the glass expert employed there, and indeed to prepare new glasses directly from the optical specifications when needed. A special heavy flint, for example, which was desired by the Government, was made with no more than two trials. To properly appreciate just what this progress means, it may perhaps be recalled that in the days of rule-of-thumb glass making, as many as 150 essays were necessary before a glass of predetermined optical constants resulted. This kind of knowledge applied intelligently commanded for the Laboratory workers the immediate respect and confidence of the workmen who had hitherto believed these things to be shrouded in impenetrable mystery, and contributed in no small degree to the rapid progress and whole-hearted coöperation obtained.

Again later in the war, when the development of airplanes made it necessary to prepare a new type of airplane camera for battlefield photography, a special barium glass was made upon comparatively short notice which fulfilled the optical requirements with little if any variation.

Perhaps a brief digression may be permitted here to indicate the suddenness with which perplexing problems were precipitated by special inquiries like this. Most of the optical glasses in general use fall into two types, generally designated as flint and crown, both of which when melted form viscous mixtures which give little difficulty except in maintaining homogeneity. The barium crowns and flints, on the other hand, appear almost as thin as water in comparison and possess the disadvantage that they are taken up by the pots almost as rapidly as coffee is taken up by a lump of sugar. The most serious question encountered in connection with the barium glasses therefore was not to discover the composition appropriate to the prescribed optical constants, but to provide a suitable container in which the ingredients could be melted.

There is one other problem to which allusion should be made which is on the whole the most persistent and difficult problem encountered in the entire glass technique; it is the question of obtaining a homogeneous product. By this the glass-maker understands primarily freedom from striations or cords. It is fairly obvious that in a mixture, parts of which are volatile and into which other ingredients are entering through the solution of the

containing vessel, inhomogeneity is constantly to be feared. Moreover, in the heavier glasses the differences of specific gravity among the ingredients amount to as much as three or four to one. These are the causes of the glass-maker's cords and striations, of which traces are found in the finest product of the glass-maker's art. It is to meet this situation that stirring is resorted to at several stages of the process.

Theoretically, if the stirring were vigorous enough, homogeneity would result except for the losses due to evaporation and the accessions (chiefly of alumina) from the pot wall; practically, this result is not so simply attained. Practically, indeed, perfect homogeneity in glass melts is unobtainable. Alumina in particular, even when present in very small quantity, yields a glass of lower refractive index than the surrounding mass and becomes immediately conspicuous. Incomplete solution of silica grains will sometimes leave a train through the mixture resembling a comet's tail. Such striations are very persistent and require stirring, either constantly or at frequent intervals, not only during melting but during the cooling, in order to diminish, so far as possible, the convection currents or other migration within the melt. Even with all the precautions taken which the experience at the several factories suggested to us, rejections by Government officials were mainly on account of striations.

Toward the close of the war a new scheme of melting was developed, partly in the hope of providing a quicker process than the normal one and partly in order to render the striations innocuous by orienting them perpendicular to the plane of light transmission. This consisted in melting and stirring in very nearly the usual way, but instead of setting out the pot to be slowly cooled through a period of several days in order to be able to break it up without undue losses, the hot glass was taken from the furnace and poured upon a steel table in front of an advancing roller which rolled it out in a sheet, similar to the procedure in the manufacture of ordinary plate glass. Cooling the glass in the pots made it possible to reject the outer portions of the glass mass wherein usually the striations were found concentrated. Pouring left all of the striations in the finished product, and perhaps aggravated them somewhat, because the pouring had to be done at a temperature where the glass was by no means free from them. The results obtained by the rolling process, however, were fairly

satisfactory, excepting for the most exacting requirements, because the striations were rolled out in planes parallel to the surface of the plate, so that it was possible to cut lenses from such a sheet in which the striations should all be perpendicular to the line of sight. Such glass was in general not well adapted for prisms or other optical forms through which light must pass by more than one path, but for lenses, even of considerable size, it proved satisfactory.

It should be borne in mind perhaps that when glass must be produced in vast quantities for a war emergency the utmost requirements of precision may not be exacted; indeed, deliberate relaxation may become necessary. As soon as the standards arbitrarily fixed by the War and Navy Departments had been attained further efforts to improve the quality of the glass gave place to efforts to increase the quantity practically without limit. It is therefore not quite fair to say that the war glass produced in this country was equal to or superior to that obtainable from abroad before the war. Strictly speaking, this result was not attained, nor indeed attempted, although the technique was so far perfected that it was within the power of those who participated to produce glasses of quality equal to those made abroad when necessary. In fact, through the application of phosgene to remove the traces of iron from the sand and from the pots, it is altogether probable that greater transparency could be obtained than is usual in European glasses. It is in this quality of transparency alone that American glasses have usually fallen somewhat behind their European prototypes. A process for the employment of phosgene for this purpose was successfully developed by Lieutenant S. F. Cox in the Bausch & Lomb plant during the Summer of 1918, but did not come into general use because the time required for such purification could be better spent, in the prevailing emergency, upon increased production rather than upon a superfluous refinement.

It also proved practical to carry out the entire melting process within a period of 24 hours. Where before the war two weeks was not an uncommon period through which to nurse the melting operation in order to secure the best results, a 24-hour schedule was worked out by Doctor Morey at the Spencer Lens Company's plant under which glass equal in quality to any which was supplied to the Government during the war period was produced.

In so brief an outline as this must be, it is perhaps unnecessary to consider other details of the process of optical glass-making such as the relation between rate of cooling and the break-up of the mass with a minimum of waste, the process of moulding the raw blocks to suitable shape for inspection and suitable size for the subsequent operations of the lens maker, the grinding of opposite surfaces for inspection purposes and the details of the inspection process, and finally the painstaking annealing through the perfection of which alone accurate grinding becomes possible or worth while and a permanent configuration is assured. All these processes required time and conscientious attention to detail for their working out, and in general require modification for each type of glass made, but they set no problem for the chemist and physicist beyond the requirement of endless patience and attention to detail.

Of the results of these efforts it need only be said that within a period of four months after the entry of the United States into the war the production of optical glass within this country had been doubled, the methods had been rendered more effective, the number of types had been increased and, moreover, a degree of confidence had been established indispensable for the state of the times and of the task. I quote from a memorandum of Doctor Wright, written on July 28th, after three months of experience in the manufacture of optical glass at Rochester: "In the course of our work we have realized that the making of glass of high quality is not beset with mysteries to be solved only by the intuitive genius of one specially trained in the art, but that it is a straightforward scientific problem, requiring for its solution the application of methods of attack and control common to all scientific problems of high precision."

I venture to remark that before the beginning of this experience at the Bausch & Lomb plant no member of the group of men who undertook the war work there had ever followed a pot of glass through the process of melting. Moreover, with the long record of secrecy continuously maintained in two of the glass producing countries, and in the third also, except for a portion of its early history, no information was available from without. Here as in many other cases, however, when the details are finally brought to light by time, the maintenance of secrecy has frequently been shown to be a cloak to cover limitations rather than

profound knowledge. The processes of glass-making are simple and the traditions of the glass-house are as often the result of cumulative superstition as experience. The heart of the whole matter lies in the relations between the ingredients at the various temperatures through which they pass and their reaction velocities. The solution of these relations is not a task for the glass-house, but rather for the most exacting application of silicate chemistry at high temperatures.

The Geophysical Laboratory has published freely the results of its experience in the glass industry, and in so far as this experience was not available before, it is so now for any individual or group who may wish to make a beginning of a permanent optical glass industry in this country.

The portion of my subject which deals with the future of the industry must, however, remain vague. Three firms entered this field, to produce optical glass on a large scale for war purposes, of whom two were able to make use of the product in instruments of their own manufacture. This portion of the industry may endure in whole or in part. The third successful producer of optical glass has to find his market outside his own plant, and this market is rather too intangible to be attractive as a business venture.

It remains true to-day, as it did during the war period, that the cost of several of the necessary ingredients is necessarily greater in this country than in European countries where similar products originate. In quality our raw materials are equally good, our experience in technique is adequate if not equally extensive with some of our European contemporaries, but the cost of potash, for example, will always lay a burden upon the American product, and other ingredients might be mentioned which fall in the same category. If there were a market sufficient to stimulate production on a very large scale these difficulties could be overcome by improved technique and organization, as in the case of other conspicuous American industries, but the demand for optical glass will probably never be large, and the incentive to large-scale processes and cheaper production will therefore probably always be lacking unless the Government determines upon a definite program of preparedness. The instrument maker may find it advantageous to make his own glass for the reason that he can then arrange for the precise optical constants which he wishes to use in his instrument, and he may have them within a period of a few

days instead of weeks or months, but the trade itself will perhaps never furnish sufficient incentive to build up a large industry in this country.

Moreover, if it may be said without appearing to reflect upon similar industries abroad, it is, I think, no secret that successful makers of optical glass in other countries have had to look for their profit in other lines rather than in their optical products.

In closing this account of the effort which was made to supply the Government with its indispensable requirements of optical glass, it gives me unusual pleasure to pay a personal tribute to the whole-souled patriotism and untiring patience of all members of the staff of the Geophysical Laboratory and of the participating manufacturing firms, without whose efforts this record would have been impossible. It is to them an everlasting credit that through their exertions the great, and, in many respects, unparalleled, task of developing an entirely new industry was accomplished, literally out of nothing in the way of special experience because of the atmosphere of secrecy with which this particular industry has been so persistently enshrouded. It was also accomplished in time for the requirements of the service.

The total quantity supplied by these firms from April 6, 1917, to November 11, 1918, the war period, is approximately 650,000 pounds,* divided as follows:

Bausch & Lomb Optical Company	450,000 pounds, approximately
Spencer Lens Company	75,000 pounds, approximately
Pittsburgh Plate Glass Company	125,000 pounds, approximately

In addition to this production the Bureau of Standards supplied a little more than 19,000 pounds, or about 2.8 per cent. of the total war-time production.

Except for occasional shipments of a few pounds from the Parra Mantois Company, in France; from the British Government plant at Derby, and that produced by the Keuffel & Esser Company, of New York, for their own contracts (about 9,000 pounds for the period of the war), no other optical glass was available to the Government for war operations.

* Informal records of the Geophysical Laboratory; the official record of the War Industries Board has not yet been released for publication.

THE INDUCTION ELECTRICAL FURNACE.*

BY

G. H. CLAMER.

Member of the Institute.

I WILL confine my lecture to the Induction Type of Electric Furnace, and trace the development of the induction furnace art. I will more particularly confine it to its application in the brass industry, especially the wrought brass industry. What is included in the designation "brass" is all copper and zinc alloys, containing from five to forty per cent. of zinc, and varying smaller percentages of tin, lead, etc. All alloys within this range of composition are not commercially so designated, but I wish it understood that in referring to brass in this lecture, I include all alloys within this range. Such alloys constitute a very great proportion of the total tonnage of copper alloys produced.

In this art, prior to the advent of the electric furnace, the rolling mills of the country adhered almost universally to the ancient practice of melting in small crucibles, having a maximum holding capacity of 300 pounds. These small crucibles are placed in a so-called "pit furnace," usually using anthracite coal for fuel.

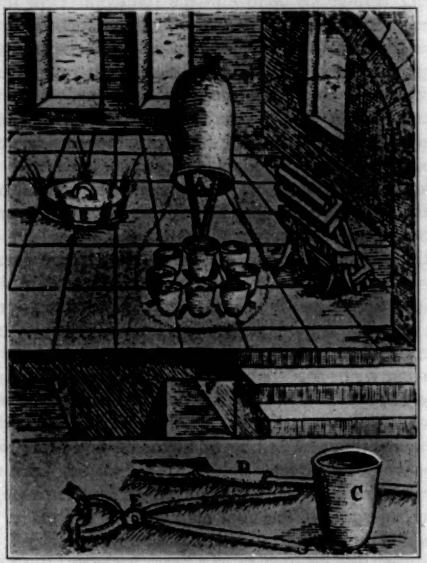
A recent writer has stated: "Of all the present-day industrial arts that have come down to us from the ancients, there is none that has changed less in the technic of its practice than brass melting. The melting and casting of the metal in a brass mill is the most important step in the whole process of making brass material, because any failure here cannot be rectified by later manipulation. However, in spite of the vital character in this stage, it is the one in which the least advancement has been made."

An interesting illustration of a brass foundry (Fig. 1) appearing in Ecker's "Untererdische Hofhaltung," published in 1682, bears a truly remarkable resemblance to the equipment of the casting shop of our largest and most modern brass mills. The only radical difference between the furnace as shown, and the typical modern pit furnace, lies in the method of carrying away the products of combustion.

* Presented at a joint meeting of the Institute and the Philadelphia Section, American Institute of Electrical Engineers, held Wednesday, March 17, 1920.

In the modern furnace the products of combustion are carried off on the side and into the stack, thus increasing the rate of combustion and also adding to the comfort of the workman, whereas in the ancient furnace the products of combustion were allowed to escape into the open shop. The method of handling the crucible and pouring the brass into the molds, and the type

FIG. 1.

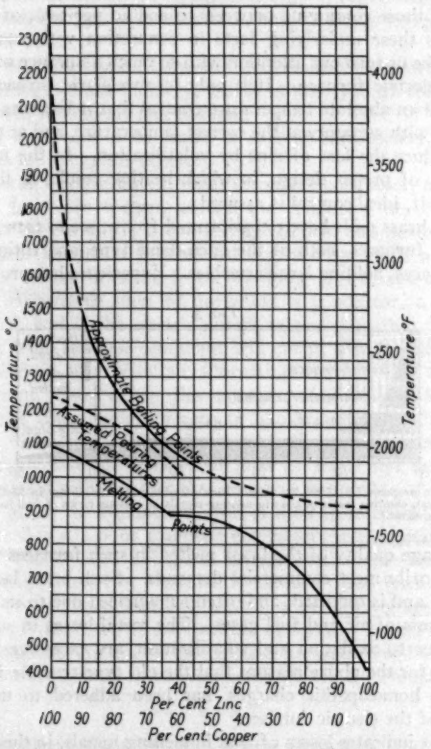


Ancient brass mill. Illustration in Ecker's "Untererdische Hofhaltung," published in 1682.

of molds used, were not radically different from the method and equipment in use to-day.

A very interesting curve prepared by H. W. Gillette of the Bureau of Mines is shown in Fig. 2. The lower curve shows melting points of the various copper-zinc alloys. The upper curve is a plotting of the temperatures at which zinc is volatilized from the various alloys, and the intermediate curve shows the necessary

FIG. 2.



Curve prepared by H. W. Gillett of the U. S. Bureau of Mines, showing graphically the small difference in temperature between the average pouring temperature and the temperature at which zinc volatilizes from copper-zinc alloys. This curve illustrates forcibly the value of temperature control, such as is possible only in the induction furnace, the induction furnace being the only form of furnace in which accretion in temperature of bath ceases immediately as the circuit is interrupted.

pouring temperature. These curves are of particular interest in showing in graphic form the small margin in temperature between the pouring temperature and the point at which zinc volatilizes

from those alloys that are of greatest commercial importance, namely, those containing between 30 and 40 per cent. of zinc.

It is these underlying facts in connection with such alloys that make us turn our attention with so much assurance of success to the electric furnace. It is only in an electric furnace which provides an absolute temperature control that it becomes possible to pour with certainty at the correct temperature, and at the same time reduce the loss of zinc by volatilization. In the induction furnace, of proper design, in which heating results in the metal bath itself, ideal control is assured.

The brass mills have experimented from time to time with oil and gas furnaces, both of the open-flame type, and tilting crucible furnaces, holding large crucibles. Experience has proved that

FIG. 3.

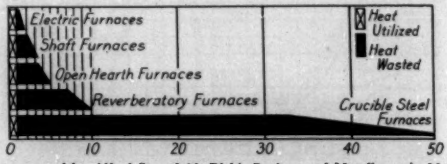


Diagram prepared by Alfred Stansfield, Birk's Professor of Metallurgy in McGill University, Montreal, showing losses of heat in melting metals in various forms of fuel furnaces, and in electric furnaces.

the average quality of the brass melted in such furnaces will not satisfactorily meet commercial demands. Such brass lacks uniformity, and is oxidized, and often sulphurized due to its contact with excess of air and fuel gases. The metal losses in such furnaces, due to oxidation and volatilization, are excessive.

It is for the above reasons that the old type crucible furnace, with its homœopathic charges, has been adhered to until the advent of the electric furnace.

Fig. 3 indicates losses of heat in melting metals, in the various forms of furnaces. The light spaces showing the proportion of the heat utilized, and the dark spaces the proportion of heat wasted.

Electric furnaces have been variously classified, but a general classification can be made under two heads:

1. Those in which the heat is transferred to the metal from an outside source.

2. Those in which the electrical energy is converted directly into thermal energy in the metal to be heated, due to its resistance to current flow.

It is the latter type of furnace that is most extensively used in the wrought-brass industry, and it is this type of furnace to which I will confine my talk to-night.

Such a furnace is in reality a current transformer, and is known as an induction furnace.

When an electric current flows through a conductor, magnetic lines of force are formed around the conductor in concentric rings. If the current is discontinued, this field dies down similar to a rubber band that is stretched into a large circle and then released. These lines of force, in dying down, cut the conductor. Whenever lines of force cut a conductor, a voltage is induced, and if the electric circuit is placed so that the lines of force from the first conductor will cut it, then a voltage will be induced in it. With an alternating current, the value of the current, and, hence the number of lines of force, is continually changing from zero to a maximum and then back to zero. The rate of this change is called the frequency. In order to increase the number of lines of force and have them take a certain path in order that as many as possible of the lines will cut all of the conductors, iron is used to interlink the conductors. Air is a poor magnetic conductor; iron is many times better. The induced voltage is proportional to the number of cuts in unit time. For example, if we have 1000 lines of force cutting 10 conductors in one second, a certain voltage will be induced. Now, if we double the lines of force or double the number of conductors or cut the time in half, the voltage will be double. We may now express these three conditions in a formula:

$$V = C \times F \times T \times L$$

V = the voltage, C = a constant, F = the frequency, T = the turns, L = lines of force.

The combination of two coils and an iron core interlinking them constitute what is called a transformer. By means of a transformer any voltage desired may be obtained, either higher or lower than the supply voltage. Formula (1) applies to both coils of a transformer, the primary coil being the one connected to the supply; the secondary coil the one with the changed voltage.

As the constant C, the frequency F, and the number of lines L are the same for both coils, then it follows that the voltage is proportional to the number of turns. This may be expressed in a different way, as follows: "The voltage per turn is a constant."

For example, if the primary voltage of a transformer is 220 and the primary coil has 22 turns, the voltage per turn is 10. Now, if the secondary coil has 5 turns, its voltage will be 5×10, or 50. If the turns of the secondary be changed to 10 turns, its voltage will be 100. The efficiency of a transformer will average about 97 per cent., therefore, for simplicity, we may say that the input equals the output. Let P_1 equal the primary power, P_2 equal the secondary force, E_1 equal the primary volts, E_2 the secondary volts, C_1 the primary current, C_2 the secondary current, T_1 the primary turns, T_2 the secondary turns. Then

$$P_1 = E_1 \times C_1 \qquad P_2 = E_2 \times C_2$$
$$P_1 = P_2 \qquad E_1 \times C_1 = E_2 \times C_2$$
$$\frac{C_1}{C_2} = \frac{E_2}{E_1} = \frac{T_2}{T_1}$$

The current is inversely proportional to the voltage and inversely proportional to the number of turns.

The foregoing rules are of great importance in the design of transformers and also of induction furnaces, for an induction furnace is simply a short-circuited transformer under control. It is an ordinary transformer in which the secondary is formed by molten metal.

There are two injurious factors to guard against in the design of horizontal open-ring induction furnaces—namely, "pinch effect" and low-power factor.

"Pinch Effect."—When high currents are sent through molten conductors, the cross-section of the conductor tends to contract. This contraction will, if the current be sufficiently increased, finally interrupt the circuit at the point of smallest cross-section. This does not occur when steel is being melted in the induction furnace, if the furnace be not forced. Because of the high resistance of steel, the current required to melt is not sufficient to cause the "pinch effect." But, in the case of low resistance metals, as copper and brass, "pinch effect" interferes with the proper running of the furnace. This condition occurs only in induction furnaces which have the molten secondary in a horizontal plane, and of the open channel type.

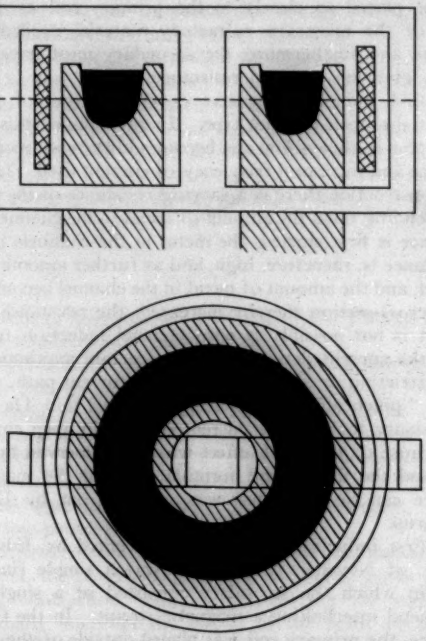
Low Power Factor.—It is essential in the proper design of a transformer to have the primary and secondary coils as closely together as possible. If this is not done, many of the lines of force will not interlink the two coils, and, hence, a low power factor will result. In the induction furnace, the molten secondary cannot be placed so closely to the primary coil as desired on account of the necessary refractory material needed for heat insulation, and furthermore, the secondary must have a certain length to give the required resistance.

The first induction furnaces developed were of that form known as the open channel type. In furnaces of this type, the power factor is always low and becomes lower with increased size of furnace and increased frequency of current used. In furnaces of this construction there is a varying resistance of the secondary loop, depending upon the amount of metal in the channels. When the furnace is first started, the metal in the channels is low and the resistance is, therefore, high, and as further amounts of metal are added, and the amount of metal in the channel becomes greater and the cross-section thereby increased, the resistance is diminished. It is not possible in open channel induction furnaces to increase the current density beyond a certain maximum because of the restriction or actual break of the current path, due to the so-called "pinch effect" previously referred to. The fact that it is necessary to limit the current density in open channel furnaces because of the pinch effect was first observed by Dr. Carl Hering and the theory and formula whereby the magnitude of this force can be calculated was worked out by Dr. Edwin F. Northrup.

The first induction furnace was invented by Edwin Colby (Fig. 4), of Newark, N. J. This was a simple ring type of furnace in which the secondary consisted of a single turn of molten metal interlinking a magnetic circuit. In the Colby type of furnace, the primary coil was placed outside of the secondary circuit. Colby was in the platinum business and his desire was to produce a furnace in which platinum could be melted in a non-carbonaceous atmosphere. Platinum, when melted in contact with carbon, absorbs that element to some degree and makes it difficult to work. Colby did not succeed commercially in accomplishing that which he set out to do, but he did give to the world a type of electric furnace which for many other purposes

has been developed into one of great usefulness and importance. From a theoretical standpoint, this type of furnace is of the highest efficiency, and is one in which the charge of liquid metal is under perfect temperature control. In the induction furnace the

FIG. 4.



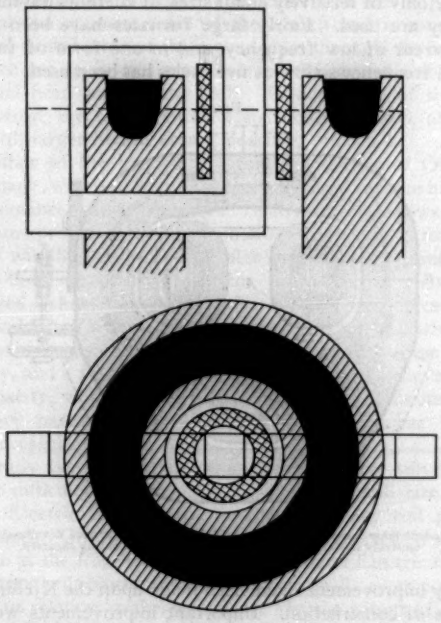
Original open channel induction furnace as invented by E. A. Colby, 1888. In this furnace is embodied the basic idea upon which was founded the Induction Furnace Art.

heat is generated within the metal itself and the current flow is absolutely steady, because of the constant resistance.

Deferranti, in England, patented a similar induction furnace at approximately the same time as Colby. He also placed the primary coil outside of the secondary, the magnetic leakage was therefore very great and the power factor quite low. Both Colby

and Deferranti, no doubt, were afraid to place the primary within the secondary circuit because they had not worked out a proper means for protecting the primary coil from the effects of heat generated in the molten secondary.

FIG. 5.



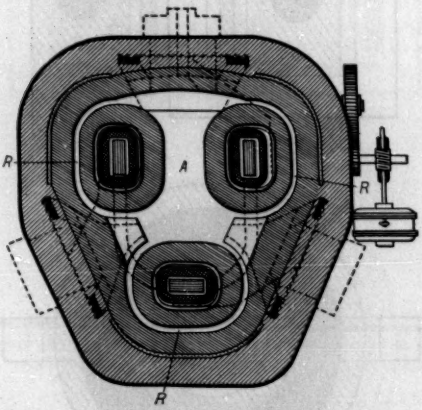
Invention of Kjellin which made possible, by reason of the improvement in power factor as compared with the Colby furnace, commercial application of the induction furnace.

Kjellin a few years later patented a furnace (Fig. 5) in which the primary coil was placed within the secondary. Magnetic leakage was thereby greatly reduced and the power factor, on furnaces in which the secondary ring was of relatively small diameter, could be maintained quite high. With increasing diameter of the secondary ring, the power factor becomes correspond-

ingly lower. It was this invention of Kjellin that put the induction furnace in position to become a commercial competitor of the arc type of furnace for steel melting.

Because of the effect of the size of the secondary ring on the power factor, the Kjellin type of furnace could be applied commercially only in relatively small sizes, if currents having normal frequency are used. Fairly large furnaces have been made by using current of low frequency, and in one form of furnace of this type, frequency so low as five cycles has been used.

FIG. 6.



Röchling-Rhodenhauser furnace. A commercial form of steel furnace developed and used extensively in Germany in sizes up to eight tons holding capacity.

Many improvements have been made upon the Kjellin furnace in details of construction. Important improvements were made by Colby covering design of transformers, having as their object the cooling of the primary coil and greater ease of dismantling.

One of the greatest improvements is embodied in the now well-known Röchling-Rodenhauser furnace. A two-phase furnace of this type (Fig. 6) is nothing more than two Kjellin furnaces placed together and in which the working hearth forms a section of the secondary circuit of each of the phases. It is possible, by restricting the cross-section in the channel portion

of the secondary loop, to maintain a fairly high resistance and cut down the magnetic leakage. By reason of the common hearth resulting by this construction, fair-sized working space is provided. Magnetic leakage is further cut down by placing an auxiliary coil in such position that current of relatively high voltage is inducted therein. This current is led to pole pieces placed at the opposite sides of the hearth and is conducted by means of a conductor of the second class through the bath. The resistance set up in this conductor of the second class provides additional heat units to the bath. In a furnace of three-phase construction, the same general construction is used, and in this case a still larger hearth area is possible.

Another of the important inventions is that of Otto Frick, of Germany, which is an attempt to provide a furnace having low self-inductance, and therefore relatively high-power factor. The means provided for accomplishing this result is to place the primary winding above the annular hearth, constituting the secondary, both the primary and the secondary, of course, being interlinked by the magnetic circuit. Certain mechanical features are provided, affording greater convenience in operating. This is a type of furnace which has been introduced to some extent in Germany, and a few years ago a large furnace, I believe of thirty tons capacity, was installed in Lebanon, Pa. This installation, due more particularly to refractory troubles, has been far from succesful.

Recently the General Electric Company have solved the refractory difficulty, at least for furnaces of small size. In the General Electric furnace, the overhead primary coil placement is also used. One furnace of this type is reported in successful operation at the Pittsfield plant of the General Electric Company.

Primary coils have been placed in practically every conceivable position in relation to the secondary. In the patent of C. Grunwald, a construction is provided whereby the "motor effect" due to the repelling force of the current in the primary winding upon the secondary is counteracted, the result of this repelling force is to bank the liquid metal at the outer circumference, which causes an inclination of the exposed surface of the bath. Such inclination of the bath exposes the high surface to oxidation, and pockets slag in the depressed area, thus causing rapid deterioration of the lining surrounding the smaller diameter of the channel.

A number of patents have been issued to Hiorth, but apparently none of these have come into commercial use. In one of his inventions he shows a placement of primary coils permitting of greater accessibility to the bath. Two primary coils are used. One above the bath, and one below. The upper coil having a smaller diameter than the secondary channel, and the lower coil having a greater diameter than the secondary channel. In another of his inventions, he attempts to overcome one of the most serious objections to the induction furnace as a means for refining steel. It is claimed that in the ordinary induction furnace, slag action does not proceed rapidly because the slag is relatively cooler than the metal. The reverse condition exists in the arc type furnace. In the arc furnace, the slag is necessarily hotter than the metal, and it is claimed that due to this fact the refining action proceeds at a very rapid rate.

Hiorth accomplished the heating of the slag by providing a dam, or obstruction, in the path of the secondary channel, whereby the flow of current is diverted to the slag above the obstruction. As the slag is of relatively high resistance, there is a rapid conversion of electrical energy into thermal energy at that point. The temperature of the slag is thereby raised, and more energetic slag action supposedly results.

Grönwall Lindblad and Stälhane have invented a furnace of the ordinary ring type providing an elongated portion of the ring in the form of a loop, the channels of which are brought into close proximity, thereby cutting down self-induction. With such construction of the secondary a bath of higher resistance is provided, having greater holding capacity without diminishing the power factor.

A furnace similar in principle to that of Grönwald Lindblad and Stälhane was invented by Gin. In this furnace a number of loops are used giving a circuit of relatively high resistance which therefore permits of the use of higher voltage, and gives a high-power factor. This furnace was not successful because of refractory difficulties. Highly heated metal on two sides of a refractory wall, without cooling provision, is not practicable.

A further invention of Gin provides a means for circulating the liquid metal of the bath. Instead of the usual ring, a series of inclined connecting channels are provided. The bottoms of the receptacles of the bath are longitudinally sloping, and the top

portion of each receptacle is connected by a channel to the shallow portion of the next. The "Joule effect" which varies in an inverse ratio with the section of the molten mass is less intense in the top portion of the open channels. As the two liquid masses, which connect through closed conduits, have different densities on account of the difference in temperatures, an upward movement of the liquid molecules in the closed channels is produced. Continuous circulation thereby results.

Solomon is credited with an invention which provides for the usual annular secondary, constructed in the form of a removable crucible. The secondary having its magnetic circuit broken by a section of butt joint construction permits of the convenient withdrawal of the crucible. Mechanical means are provided for ejecting the crucible.

Geherkens uses a construction which restricts it to melting low-fusing point metals. The secondary in this furnace forms the outside casing or furnace chamber. The walls of same are of relatively great cross-section, so that heating effects are at a minimum. Two sections of the secondary circuit are so designed that they are of relatively small cross-section. In these sections of restricted cross-section, heating effects are produced, and the heat so generated is transferred to the metal bath, and an insulating lining keeps the bath from coming into electrical contact with these resistors.

Charles P. Steinmetz invented a furnace which can be described as a cascade induction furnace in that there is a double transformation. Both transformations are provided under conditions of minimum magnetic leakage. In the first transformation the secondary takes the form of a water-cooled casting, and the bath to be heated is contained therein, in the form of a ring-shaped channel, electrically insulated from the casting. A magnetic circuit interlinks both the casting and the bath, so that a second transformation results. There is no record, so far as I know, of this furnace ever having been used.

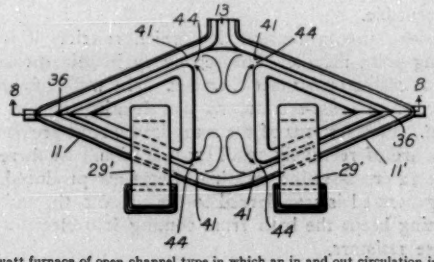
A patent to James R. Wyatt (Fig. 7) discloses an open ring furnace of the Röchling Rhodenhauser type, in which is provided more rapid circulation due to "motor effect." "Motor effect," as I will later on describe, occurs at the acute angles "36" because the current path at such points takes opposite directions. Owing to the more rapid circulation thus produced, as compared with

the circulation in the Röchling-Rhodenhauser furnace, considerable advantage results, namely, more rapid refining and diminished destructive effects upon the lining, due to the more rapid ejection of the overheated metal from the channels.

A furnace designed by Benjamin has for its object a means for counteracting the banking of the bath due to motor effect. I have before described how Hiorth accomplished this by electrical means. Benjamin seeks to accomplish the same effect by mechanical means.

A furnace invented by Bally operates on an entirely different principle than the many other furnaces before exhibited, in that

FIG. 7.



Ajax-Wyatt furnace of open channel type in which an in and out circulation in each leg of the secondary loop is provided. This circulation results by reason of the fact that the current in turning an acute angle travels in opposite directions in the conductor on the two sides thereof.

inductive effects result in this furnace by reason of a rotary field and a stationary armature. If in an induction motor the armature is so wedged that it can not rotate, it burns out, because of the rapid conversion of electrical energy into heat instead of motion. In this furnace the bath to be heated is the armature. The inductor with an exciting current rotates within the annular bath or armature and heating thereby results.

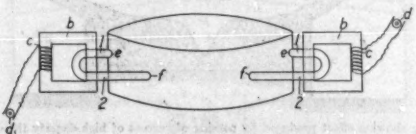
All the furnaces thus far described are of the open-channel type.

Charles P. Schneider, President of the Creusot Steel Works of France, and immediate past President of the British Iron and Steel Institute, was the original inventor of the closed channel induction furnace in which there was a pool of metal that exerted a hydraulic pressure upon the molten metal in closed

channels or channels constituting the secondary loop. In the furnace as described and constructed by Schneider, a constant resistance of the secondary is maintained. In this type of furnace the power factor can be made relatively high because it is possible to have comparatively close looping of the secondary and because of its high resistance. It is claimed by Schneider that circulation is maintained by thermal effect. Pinch force was present in the Schneider furnace, but not recognized—at any rate, the hydraulic head resulting from the head of metal over the liquid metal in the channels was sufficient to prevent rupture of the circuit if pinch force of such magnitude were present which in an open channel furnace would break the circuit.

The Schneider furnace is shown diagrammatically in Fig. 8. This plate shows circular melting pot in communication with two

FIG. 8.



Original closed channel induction furnace invented by C. P. Schneider, President of the Creusot Steel Works, France, and past President of the British Iron & Steel Institute.

"U"-form heating tubes 1 and 2, slightly inclined in such a manner that their communications *e* and *f* with melting pot are at different levels. Through each loop, formed by tubes 1–2, passes a magnetic frame or iron core (*B*) carrying primary winding (*C*) traversed by alternating current coming from dynamo (*D*), whereby magnetic lines of force are produced in the iron core (*B*).

Schneider was the first to heat a pool by circulation of metal from an outside resistor channel and to cause *also circulation of the pool thereby*. This, in his patents, he claims broadly as follows: "In combination a chamber for holding molten metal, one or more pipes communicating with said chamber so constructed as to permit circulation of molten metal, an iron core encircling said pipe or pipes and means for producing lines of force in said core."

The Schneider furnace was not successful because the circulation was sluggish and overheating resulted in the resistor channels.

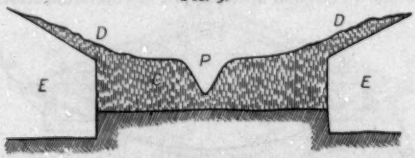
Other closed channel furnaces have been invented by Deferranti and Wallin.

The Deferranti furnace differentiates from the Schneider in that it shows the transformer in a horizontal position, and the furnace is arranged to tap from the bottom.

In the Wallin furnace the secondary loop is also placed in a vertical position, but in this case part of the secondary is made up of slag or ore mixture having relatively high resistance. It was Wallin's idea to combine a vertical ring induction with a shaft furnace.

As I have stated before, about 1909 Dr. Carl Hering observed the "pinch effect" in a molten circuit carrying current of high density.

FIG. 9.



Drawing showing effect produced by passing of current of high density through a molten conductor in a straight open channel. The body of liquid metal contracts in the centre and flows up over the electrodes. As the physical appearance is that of pinching the molten conductor, the phenomenon has been termed "pinch effect" by Dr. Carl Hering, who first observed it.

Doctor Hering passed a very heavy current through the molten metal contained in a trough between two electrodes "*E*" (Fig. 9). When the current reached a certain density, a severe depression occurred at point "*P*" and the liquid metal flowed back over the electrodes at "*D*." He at first thought that a leak in the bottom of this trough had allowed the metal to run out. An examination showed that this was not the case, but that it was due to electrical action.

His observations were recited to Dr. Edwin F. Northrup, who, as I stated before, explained the phenomenon and worked out the mathematics in connection therewith. Then with an understanding of the magnitude of this force, Doctor Hering applied it to useful advantage in the construction of an electric furnace.

He passed the current through a channel submerged below molten metal (Fig. 10). The current then, if of sufficiently great density, causes the metal to circulate as shown.

In the furnace as originally constructed by him, current was

led by electrodes to columns of liquid metal retained within a tubular wall. These columns of metal were of relatively small cross-section and carried currents of high density. The circuit was com-

FIG. 10.

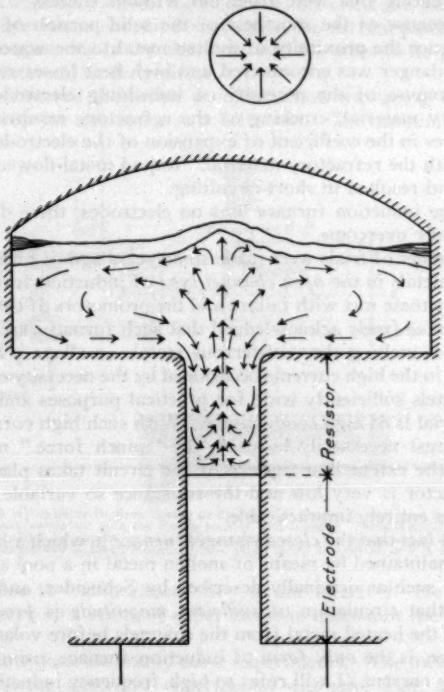


Diagram illustrating the action of "pinch force" as applied in the Hering Electrode Type Furnace.

pleted by the metal bath. Heat was developed in the metal in these tubes, known as resistors, and energetic circulation ensued by reason of the "pinch force."

Certain inherent difficulties became apparent in the Hering

electrode type of furnace as the development work progressed. Briefly, these are as follows:

1. Melting of electrodes back to the point where further melting was only prevented by the water cooling. Many means for preventing this were tried but without success.

2. Because of the shortness of the solid portion of the electrode, hence the proximity of molten metal to the water, an element of danger was encountered and high heat losses resulted.

3. Because of the necessity of imbedding electrodes in the refractory material, cracking of the refractory resulted, due to differences in the coefficient of expansion of the electrode as compared with the refractory material. Liquid metal flowed in these cracks and resulted in short-circuiting.

As the induction furnace uses no electrodes, these difficulties are entirely overcome.

A number of trials were made some years ago of melting non-ferrous metals in the *open channel type* of induction furnace, but invariably these met with failure and the promotors of this type of furnace have freely acknowledged that such furnaces are not successful for melting the non-ferrous metals or alloys. The difficulty lies in the high currents occasioned by the necessity of having the channels sufficiently wide for practical purposes and because the material is of high conductivity. With such high current density as must necessarily be used, the "pinch force" manifests itself to the extent that rupture of the circuit takes place. The power factor is very low and the resistance so variable that the furnace is entirely impracticable.

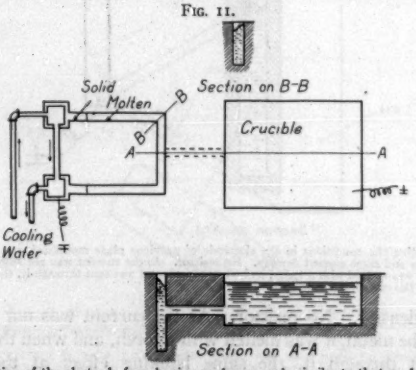
It is a fact that the *closed channel furnace* in which a hydraulic head is maintained by means of molten metal in a pool above the channels, such as originally described by Schneider, and so constructed that circulation of *sufficient magnitude* is *produced* to *eliminate* the heated metal from the channels before volatilization takes place, is the *only form* of induction furnace, using normal frequency current (I will refer to high frequency induction heating later), that has promise of commercial success for melting non-ferrous metals.

I was associated with Doctor Hering in the development of the electrode "pinch effect" furnace, as was also Mr. James Wyatt. As before stated, one of the main difficulties to be overcome in this form of furnace is to prevent melting of the electrodes. It

was thought that such melting was largely the result of "pinch pressure" which exerts its force in both directions from the centre of the resistor. Hot metal is forced inward against the electrode as well as upward into the bath. As a means for preventing a backward circulation within the electrode, the electrode was made of right-angle form. In this construction the current path turned two right angles, one in the electrode, and the other in its passage from the electrode to the resistor.

Wyatt observed that some peculiar action was going on in a steel furnace with electrodes so constructed. The question arose,

FIG. 11.



Duplication of the electrode form having 90 degree angle similar to that used in the three phase steel furnace, connected with the Hering resistor, and crucible. Decided action of metal on the line *BB* piling up against outside walls was observed. We questioned if this action was due to backward flow of metal resulting from "pinch force" in resistor, or if it was due to "motor effect."

Was this due to "skin effect" or "motor effect"? He determined to carry on a series of experiments to determine the underlying cause.

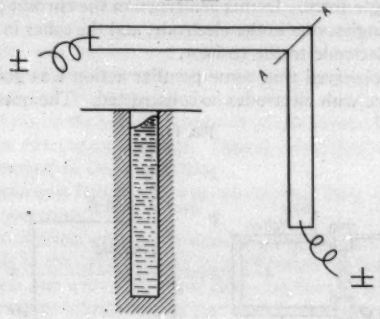
I will now describe briefly those experiments. The metal used in the following described experiments was pure lead, and the forms were moulded in ordinary moulding sand.

(Fig. 11.) Duplication of the electrode form having 90-degree angle similar to that used in the three-phase steel furnace, connected with the Hering resistor, and crucible. Decided action of metal on the line "*BB*" piling up against outside walls was observed. We questioned if this action was due to backward

flow of metal resulting from "pinch force" in resistor, or if it was due to "motor effect."

(Fig. 12.) Duplicating the conditions in the electrode of previous plate maintaining the same cross-sectional area and same

FIG. 12.

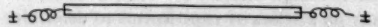


Duplicating the conditions in the electrode of previous plate maintaining the same cross sectional area and same current density. No resistor. As the current was not sufficient to melt the metal, it was melted with a torch, and when the current was sent through it, the same banking effect at the corner *AA* resulted.

current density. No resistor. As the current was not sufficient to melt the metal, it was melted with a torch, and when the current was sent through it, the same banking effect at the corner "*AA*" resulted.

(Fig. 13.) Again duplicating the same conditions existing

FIG. 13.

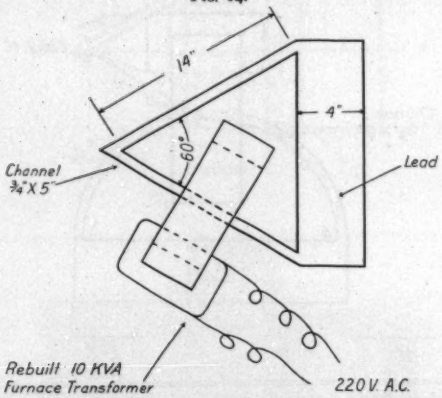


Again duplicating the same conditions existing in the electrode, Fig. 11, but without Hering resistor, and without angle of Fig. 12. Here again the metal was melted with a torch, and when the current was turned on there was no action, the current being insufficient to cause a noticeable "pinch effect," this experiment being on cross sectional area of electrode proportions. No action visible.

in the electrode, Fig. 11, but without Hering resistor, and without angle of Fig. 12. Here again the metal was melted with a torch, and when the current was turned on there was no action, the current being insufficient to cause a noticeable "pinch effect," this experiment being on cross-sectional area of electrode proportions. No action visible.

(Fig. 14.) The first attempt to embody the "motor effect" idea as a means for circulating liquid metal. In this case two legs of the triangle formed the resistor, and the other leg the bath. There was a decided banking effect in the angle farthest from the bath, and banking effect of less magnitude at both angles, that the resistor formed with the bath. In the construction shown, there is a transformer, the magnetic loop of which surrounds one

FIG. 14.



The first attempt to embody the "motor effect" idea as a means for circulating liquid metal. In this case two legs of the triangle formed the resistor, and the other leg the bath. There was a decided banking effect in the angle farthest from the bath, and banking effect of less magnitude at both angles, which the resistor formed with the bath. In the construction shown, there is a transformer, the magnetic loop of which surrounds one leg of the resistor, and the primary coil is placed on one of the legs outside of the same.

leg of the resistor, and the primary coil is placed on one of the legs outside of the same.

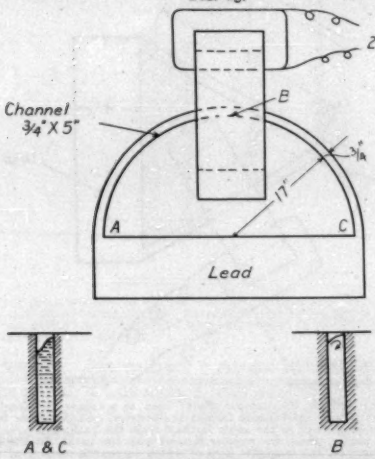
(Fig. 15.) Experiment to note the difference in action between the resistor having an acute angle and one of circular form. In this experiment the transformer was again looped about the resistor in the same manner as in Fig. 14, and it was noted there was a decided banking and overheating effect at point "*B*," and banking and choking effect at points "*A*" and "*C*." This can be accounted for by the "motor effect" set up at points "*A*" and "*C*," and the absence of "motor effect" at point "*B*."

(Fig. 16.) This shows the next attempt made to better the

power factor by placing the primary coil completely within the secondary, and to get better mechanical construction. The bath of metal in this experiment was of open-top construction. Decided motor effect was noted at the angle, and some choking at points "*B*" and "*C*."

In this experiment it will be noted that the angles "*B*" and "*C*" are 99 degrees, whereas in the previous experiment the angle

FIG. 15.



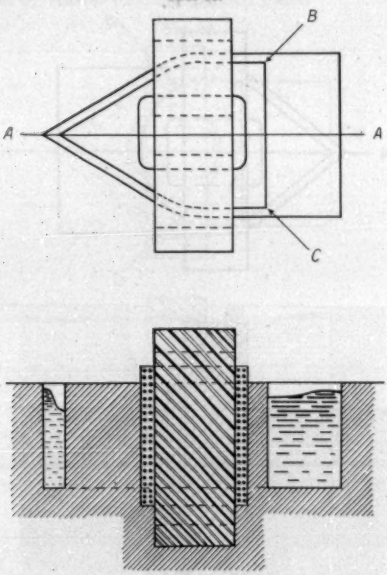
Experiment to note the difference in action between the resistor having an acute angle, and one of circular form. In this experiment the transformer was again looped about the resistor in the same manner as in Fig. 14, and it was noted there was a decided banking and overheating effect at point *B*, and banking and choking effect at points *A* and *C*, and the absence of "motor effect" at point *B*.

with the bath was 60 degrees. Less motor effect was noted in this experiment, and is explained by reason of the greater angle.

In Fig. 17 the design is such that the maximum motor effect is exerted at the angle on the cross-section line "*AA*" and the angle was eliminated at points "*B*" and "*C*." By reason of the elimination of this angle, motor effect is diminished, or absent, and the electro-magnetic force producing motor effect in the angle at "*A*," has full force in clearing the channels, there being no choking at points "*B*" and "*C*."

(Fig. 18.) Same construction as Fig. 17, with the exception that the resistor is here submerged. In the latest design of furnace the same conditions prevail, except that the resistor is in a vertical position.

FIG. 16.



Section on A-A

This shows the next attempt made to better the power factor by placing the primary coil completely within the secondary, and to get better mechanical construction. The bath of metal in this experiment was of open top construction. Decided "motor effect" was noted at the angle, and some choking at points *B* and *C*.

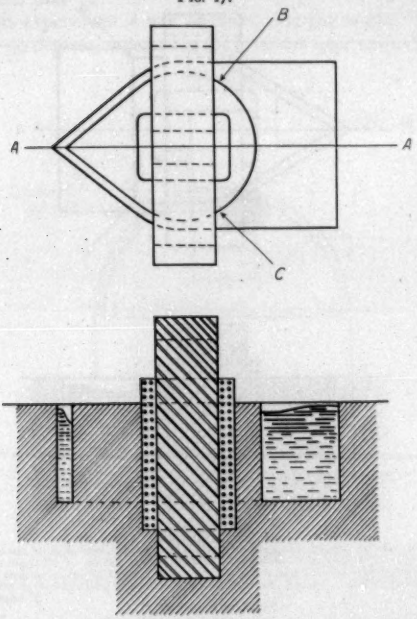
In this experiment it will be noted that the angle at *B* and *C* is one of 90 degrees, whereas in the previous experiment the angle with the bath was 60 degrees. Less "motor effect" was noted in this experiment, and is explained by reason of the greater angle.

(Fig. 19.) Shows in view one and two the vertical ring form of Ajax-Wyatt electric furnace, having in general a body or bath and a channel portion forming an acute angle connected thereto. The channel portion is interlinked with the transformer having the primary coil wound upon the central leg of the magnetic

frame, and in a position practically concentric with the resistor. Means are provided for pouring.

This furnace is similar to the Schneider furnace in that it uses a closed channel with pool above the channel, and circulation

FIG. 17.



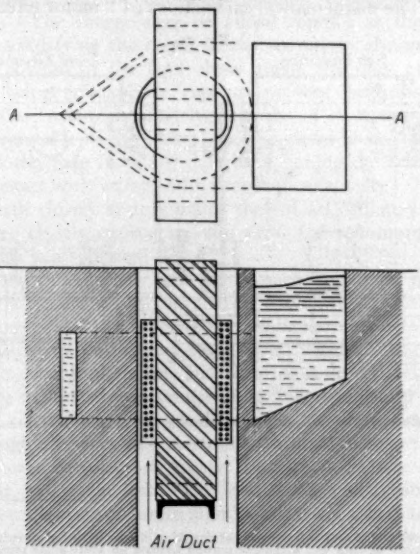
Section on A-A

This design is such that the maximum "motor effect" is exerted at the angle on the cross section line *AA* and the angle was eliminated at points *B* and *C*. By reason of the elimination of this angle, motor effect is diminished, or absent, and the electro-magnetic force producing motor effect in the angle *A*, has full force in clearing the channels, there being no choking at points *B* and *C*.

of the liquid metal in the channel. Without circulation, a furnace of this type would be entirely impracticable for the reason that it is in the channel that the heat is generated, owing to its restricted cross-section, and relatively higher resistance.

Circulation can result from "Joule" effect alone, but such circulation is very sluggish and is not sufficient for melting alloys high in volatile constituents. To melt such alloys the circulation must have sufficient rapidity to prevent volatilization and breaking of the circuit by reason of the expanded gases.

FIG. 18.



Same construction as Fig. 17, with the exception that the resistor is here submerged. In the latest design of furnace the same conditions prevail, except that the resistor is in a vertical position.

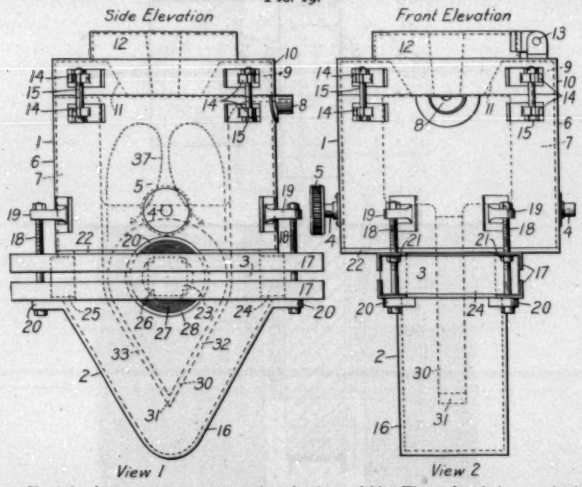
If a furnace is so designed that pinch pressure of sufficient magnitude exists, there will be a much more rapid circulation, and the circulation, due to motor effect, is still more active than that produced either by Joule or by pinch effect alone.

In the Ajax-Wyatt furnace some pinch force is exerted under existing conditions, and Joule effect also acts in an advantageous manner, but the predominating force is that resulting from motor

effect. Motor effect of considerable magnitude is set up at the acute angle which is in the current path of the secondary loop at a point farthest from the pool.

Dr. Edwin F Northrup has calculated the forces due to "motor effect" as they exist in the Ajax-Wyatt furnace and has charted these forces. Their relative magnitude is strikingly shown. The mathematical calculations of "motor effect" forces,

FIG. 19.



Shows in views one and two the vertical ring form of Ajax-Wyatt electric furnace, having in general a body or bath and a channel portion forming an acute angle connected thereto. The channel portion is interlinked with the transformer having the primary coil wound upon the central leg of the magnetic frame, and in a position practically concentric with the resistor. Means are provided for pouring.

and "pinch pressure" independently and collectively as they exist in this furnace, form a highly creditable accomplishment.

In the Ajax-Wyatt furnace it is possible to melt 60/40 brass without volatilization of zinc in the channels of the secondary circuit, so long as the cold metal is being fed into the furnace, or the bath, in its entirety, has not reached the temperature at which the zinc is volatilized. It is interesting to know that just as soon as the bath reaches the correct pouring temperature, the

needles on the instruments begin kicking. The test now used by the melter in the brass rolling mills to determine the casting temperature is to immerse an iron bar in the molten metal. If the melter feels a kick upon the bar, he pronounces the temperature satisfactory. This kick that is felt is simply due to the so-called boiling of the metal, *i.e.*, volatilization of zinc.

The furnace may be fed with turnings, cabbaged material, ingots, etc. The charge may be added rapidly as there is no danger of solidifying the metal in the secondary channels or in the lower portion of the pool above them, the only precaution necessary being to exercise care to prevent bridging of the charge. The furnace is entirely noiseless in its operation, very cool on the outside of the jacket, uses no water in cooling, therefore, absolutely safe from any danger of having the heated metal come in contact with water and its consequent results. The shape of the hearth closely approximates that of an ordinary crucible, in fact very closely approaches the ideal for minimum of heat losses, which is a spherical form.

It is possible to tightly seal the furnace to prevent oxidation. The heat is generated in the charge itself, and at the bottom of the charge. All the forces effective in the channels have the tendency to carry the heated metal upwards, *viz.*, motor effect, pinch effect, and Joule effect, and so bring it in contact with the metal to be melted, consequently there is constant and energetic automatic circulation. The conditions in all these respects are ideal for high efficiency and minimum of metal losses.

The power factor of a 30-kw. furnace is 85 per cent. and of a 60-kw. somewhat less. The load is a perfectly steady one, so that from the power-house standpoint, such a furnace load is as desirable a load as could be imagined. On furnaces that are operated on 24-hour-day schedule, the load factor approaches nearly 100 per cent.

The earlier Ajax-Wyatt furnaces have now been in commercial use in Bridgeport Brass Company mills for a period of three years. This particular mill has now twenty-four of these furnaces in operation and the total output of these furnaces, since the first one was installed, is upwards of 100,000,000 pounds. So successful has been the use of this furnace in this particular mill that the old method of melting has been entirely abandoned.

In another mill twenty-four 60-kw. furnaces are in operation,

in another sixteen 60-kw. furnaces, etc. The total tonnage of brass melted *per day* in the furnaces already installed and under construction approximates 1,500,000 pounds.

The amount of brass melted per kilowatt hour is from seven and one-half to eleven pounds, depending on the power input of the furnace, and the nature of the charge.

The theoretical figure as determined by the United States Bureau of Standards, and other competent authorities, is given at twelve and one-half pounds per kilowatt hour. This figure is based on melting two-to-one yellow brass, and bringing it to a proper casting temperature, 2000 degrees F.

In continuous melting with the 60-kw. furnace, and taking the kilowatt hours used from Monday until Saturday, and dividing into the number of pounds charged, the week-in and week-out melting rate is shown to be eleven and one-quarter pounds per kilowatt hour, indicating an efficiency of 90 per cent. This leads one to doubt the theoretical figure.

A brief summary of the cost of operation of the Ajax-Wyatt furnace as compared with the old style "Pitt furnace" can be made in the following short statement:

REPAIRS: Repair cost on electric furnace no greater than repair cost on pit furnace.

POWER: The cost of electric power as compared with hard coal fuel is practically the same.

SAVING: In addition to the above there is a great saving on labor and crucibles are entirely eliminated. Metal loss is reduced to an average of under 1 per cent., and from 5 to 10 per cent. more metal goes into production instead of scrap. This total saving amounts, very conservatively, to ½ cent per pound on the metal melted.

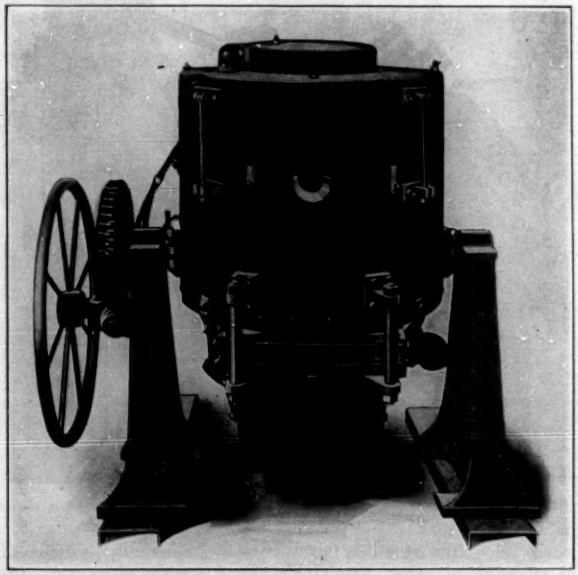
In addition to the above actual savings, there is produced a better quality of brass because of the perfect control of mixture and heat treatment, thus causing a minimum of rejections. Also, there is a decided bettering of the working conditions, an advantage which cannot be directly expressed in dollars.

In the Ajax-Wyatt furnace has been found for the first time a satisfactory device capable of replacing the ancient crucible and pit furnace. Its use in the brass mills in the country is extending with remarkable rapidity.

The Ajax-Wyatt furnace is made in two general types. One

tilting upon a central trunnion (Fig. 20) and another tilting with the pouring spout as the centre of oscillation (Fig. 21). This latter type of furnace is, of course, counterweighted for ease of manipulation. It is the latter type that is now used exclusively in the brass mills, because it permits of very satisfactory direct

FIG. 20.



Ajax-Wyatt furnace of the central trunion tilting type. This is a type of furnace used for pouring metal into a ladle and from the ladle into molds.

casting into molds. This feature, from a practical standpoint, is one of decided importance.

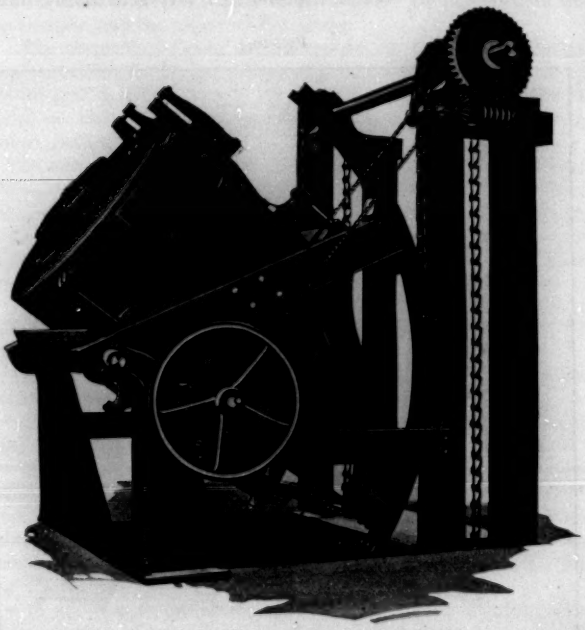
A modified method of tilting is used on the battery of furnaces shown in Fig. 22.

Having now described one form of furnace, in the development of which I have been interested, I will describe another, a

more recent development. I refer to the invention of Dr. Edwin F. Northrup, of Princeton University.

The Ajax-Wyatt form of furnace operates directly upon

FIG. 21.



Ajax-Wyatt furnace having pouring spout as centre of oscillation. This type of furnace is exclusively used in brass mills. This method of tilting permits of very satisfactory direct pouring into moulds. This feature, from a practical standpoint, is one of decided importance.

existing circuits, 25 or 60 cycle. The power factor, as I have stated, is as high as 85 on the usual 60-cycle circuit.

Doctor Northrup has succeeded in developing a commercial furnace of satisfactory power factor, using currents of relatively high frequency, namely 10,000 to 12,000 cycles per second. When currents, having frequency of the magnitude stated, are

used, splendid inductive effect is possible without interlinkage of magnetic circuit. It therefore becomes possible to heat a body of conducting material contained within the walls of a plain cylindrical form of hearth or crucible. No resistor column of molten-conducting material is necessary. Because of this fact, this furnace has a far greater degree of flexibility in its operation than is possible in any other form of induction furnace. For example, it is possible to completely melt the full contents of the hearth,

FIG. 22.

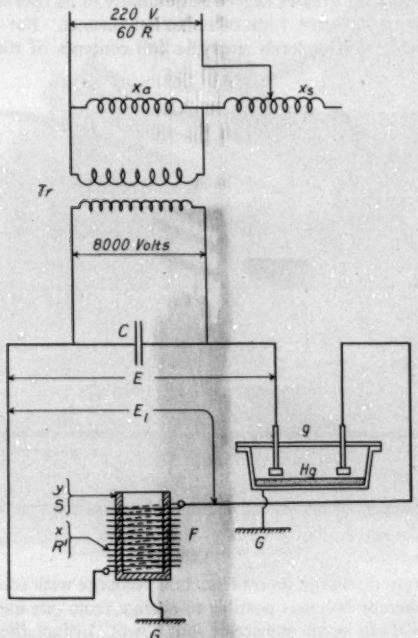
Battery of furnaces at the Bridgeport Brass Company showing a modified method of tilting designed by that company.

then entirely discharge its contents and recharge with solid material. It thereby becomes possible to change from one mixture to another without inconvenience or shut down. In fact, the furnace has all the flexibility of operation common with the ordinary crucible-type or fuel-fired furnace.

It has been found most convenient and satisfactory in the construction of furnaces under 20-kw. per phase, with a maximum therefore of 60 kw. on a three-phase circuit, to use as a source of high-frequency current, oscillatory discharge of a bank of condensers. By properly proportioning the capacity and induc-

tances of the oscillatory circuit, the desired frequency is obtained. A 60 cycle line current may be supplied at the existing voltages. A transformer steps this e. m. f. up to 8000 volts. A bank of condensors is discharged at this voltage and upon rupture of

FIG. 23.



Oscillatory current system invented and designed by E. F. Northrup for producing high frequency oscillatory currents.

the spark-gap oscillations occur (Fig. 23). The current with high-frequency oscillations passes through the inductor coil, which surrounds the crucible or mass to be heated.

This form of heating device, owing to its great simplicity and flexibility of operation and application, affords untold possibili-

ties. The high-frequency generator capable of producing an oscillatory discharge sets limitations upon the size of the heating units as previously stated to 20 kw. per phase, with power factor about 70 per cent. With a power-driven generator producing currents of pure sine wave form, the size within the commercial requirements is practically without limit.

Highly perfected generators are now on the market for wireless apparatus, and within a short time will very largely replace all static equipment in the larger stations. Such generating machines, however, are exceedingly expensive, in fact so expensive as to make their use prohibitive for heating. More recently a number of engineers have given their attention to a design of motor-driven generator to meet the demands for heating purposes. The progress already made is so very encouraging as to permit me to predict with almost positive assurance that a satisfactory generator of high-frequency current will very shortly be available at a reasonable price having one hundred or two hundred kw. capacity or multiples thereof.

Such generators are naturally of small, lightweight construction, revolving at a high rate of speed. The speed is of such magnitude that they may be driven by direct connection with a steam turbine. With the oscillatory system the furnace efficiency is about 40 per cent., and with the straight alternating current, delivered from a generator, 80 per cent., but as the generator efficiency is but 60 per cent., the ultimate efficiency is 48 per cent. The development of this type of furnace has been carried to a point that it now becomes available for many commercial operations. About 20 furnaces are in use in the most important industrial and scientific laboratories of the country, and some are filling commercial requirements in small sizes.

Three of these furnaces have recently been installed in the Philadelphia Mint for silver melting, also one at the plant of Handy and Harman, silver melters and refiners of Bridgeport, Conn. (Fig. 24), and two of them are in use by Mr. Edwin A. Colby at the Baker Platinum Works, in Newark, N. J., for melting platinum in a non-carbonatious atmosphere.

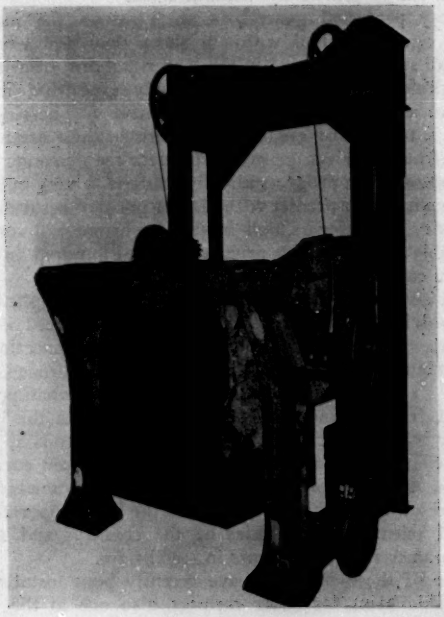
Thirty-two years have intervened since the time when Colby first gave to the world the induction furnace, and the time when he was able to secure an induction furnace that would meet his individual requirements. Thus is the fate of the inventor.

A comparison from the commercial viewpoint of these two

types of induction furnaces, namely the Wyatt and the Northrup, from our present knowledge and viewpoint, is as follows:

The Wyatt furnace is the most efficient electrical furnace as yet developed. The efficiency is so high that further improve-

FIG. 24.



Ajax-Northrup high frequency induction tilting furnace in use for silver melting at the plant of Handy and Harman, Bridgeport, Conn.

ment in this direction can be but trifling. It is exceedingly simple in construction and operation. Its electrical characteristics are of the best, and power factor of 80 per cent. is considered quite satisfactory by power companies. As at present developed, it is for single-phase operation, but satisfactory two- or three-phase furnaces will no doubt be developed in the future.

If a sufficient number of furnaces are in use to balance the phases, namely two furnaces or multiples of two on the two-phase line, and three furnaces or multiples of three on the three-phase line, the load is entirely balanced.

Small furnaces give greater flexibility of operation, but the first cost is naturally higher if two or three times the power were used in a single unit. As a portion of the charge must always remain in the furnace, it is not practicable to frequently change from one mixture to another. Furthermore, as a liquid charge is necessary for starting, it is not a furnace that can be conveniently started. It is a furnace, therefore, which should be used for 24 hours per day operation, or if used for intermittent operation, a sufficient amount of current should be kept on to supply the heat losses. This on a 60-kw. furnace is about 8 kw.

A further limitation has been put on the furnace in confining its field to melting alloys low in lead, because high lead alloys penetrate the lining material. With improved methods of lining, and a more satisfactory lining material, this drawback will also be overcome. Recent experience in this direction is very promising.

The Northrup furnace, as before stated, can be more conveniently used in intermittent service than any other furnace thus far developed. As the refractory material used is an absolute minimum in quantity, the first heat of the furnace can be taken off with almost the same rapidity and efficiency as the second, there being no great mass of refractory material to be first heated, as in other furnaces.

It is not believed that this type of furnace, because of its lower efficiency and greater cost of installation, owing to the intermediate high-frequency generator that must be used, can hope to compete with the Wyatt furnace in performing in the class of service for which this furnace is particularly applicable.

Its field will be for intermittent melting, or very high temperature melting such as required for "alloy steels," ferro alloys, precious metals, metallurgical operations, high temperature heat treating, etc.

Remarkable progress is being made in the application of electricity for heating purposes of all kinds, but as yet we have hardly scratched the surface.

Plant Fibre Paper. (*Forest Products Laboratory, News Note.*)—The laboratory receives frequent requests for information regarding the possible use of plant fibres, such as sugar-cane bagasse, corn stalks, cotton stalks, the various straws, etc., for pulp and paper manufacture.

The laboratory is restricted in its investigations to a study of the best means of utilizing our forests and forest products, so that little work has been done on the pulping of these plant fibres. From general experience, however, it is believed that these various fibres are not economical for pulping under present American conditions, as they offer the following difficulties in handling:

1. Plant stalks, straws, grasses, etc., usually contain a large percentage of pith, giving pulps low in fibre content and requiring high chemical consumption.

2. Material of this type represents seasonal crops, so that facilities must be provided for the storage of a large volume of the stock in order to permit the paper mill to operate throughout the year. The susceptibility of such material to decay adds greatly to the costs and difficulties of storage.

3. Due to the bulkiness of these materials, the digester charge is reduced, thereby reducing the yield and increasing overhead costs proportionately.

Some of these fibres, such as the straws, are being pulped at the present time for use in the manufacture of corrugated board and cheaper board products. Pulp of this nature, however, does not compare with a refined pulp such as sulphite or rag stock; it can be used only for special purposes and not in the manufacture of newsprint or high-grade paper. Plant fibres of this nature are being reduced commercially in Europe where economic conditions and the scarcity of wood permit their utilization. But under present American conditions, it is believed that such fibres can not compete commercially with wood pulp.

Salt. (*U. S. Geological Survey Press Bulletin 455,* August, 1920.)—The volume of the salt in the ocean is enough to cover the entire surface of the United States to a depth of 8500 feet.

Heats of Combustion of Organic Compounds.—THEODORE W. RICHARDS and HAROLD S. DAVIS, of Harvard University (*Journal of the American Chemical Society,* 1920, xlii, 1599–1617), have determined the heat of combustion of the following compounds. The results are expressed in 18° calories per gram of substance weighed in a vacuum: Sucrose, 3943; benzoic acid, 6320; naphthalene, 9614; benzene, 10014; toluene, 10155; tertiary butyl benzene, 10434; cyclohexanol, 8882; di-isoamyl, 11339; methyl alcohol, 5326; ethyl alcohol, 7101; prophyl alcohol, 8033; butyl alcohol, 8615; isobutyl alcohol, 8599. J. S. H.

U. S. ARMY SEARCHLIGHTS.*

BY

CHESTER LICHTENBERG.

Captain of Engineers, U. S. Army. Member of the Institute.

FOREWORD.

1. ARTIFICIAL illumination has been used in military operations as far back as written historical records are available. The story of Gideon and his three hundred lamp-bearers has been handed down from Biblical times. The use of Greek fire by the ancients is well known to students of history. In the same manner the unique employment of searchlights during the World War will undoubtedly be recorded in the story of nations.

INTRODUCTION.

2. Searchlights are relatively simple. They consist of some form of mounting, which holds a reflector and the source of light. They are usually provided with a supply of energy from an external reservoir or generator. They are used for the location and illumination of targets, for beacons and for signalling.

MOUNTINGS.

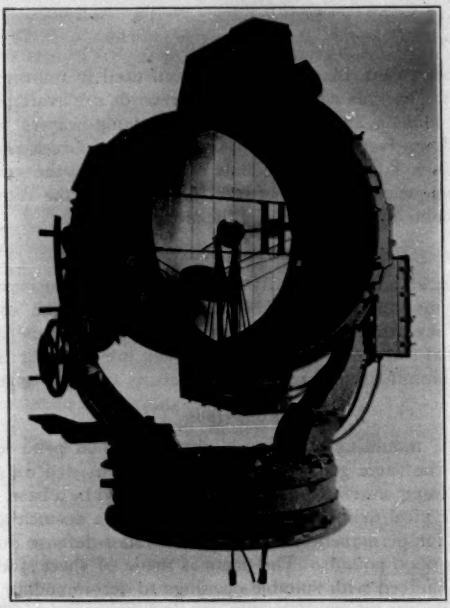
3. The mountings of searchlights furnished prior to 1918 followed the same general scheme. They consisted of a barrel or drum, hung on trunnions in a yoke supported by a base. Fig. 1 shows a typical drum-type searchlight. It is a 60-inch size and intended for permanent emplacement in coast-defense positions. It weighs 6600 pounds. The drum is made of sheet steel. The sides are pierced with suitable openings to accommodate the arc mechanism, arc viewing screens, arc regulators, etc. The rear of the drum is closed by the mirror back. The front of the drum is closed by plate-glass strips. The trunnions permit movement in a vertical plane. The yoke is pivoted to the base and permits movement in a horizontal plane. The combination allows the searchlight beam to be directed at any target within 360 degrees of azimuth and 240 degrees of elevation. The base serves two

* Communicated by the Author.

functions. It acts as a foundation for the drum and provides a shelter for any distant training mechanism.

4. Mountings underwent a startling change in 1918 and 1919. The pre-war searchlights, with very few exceptions, were heavy

FIG. 1.



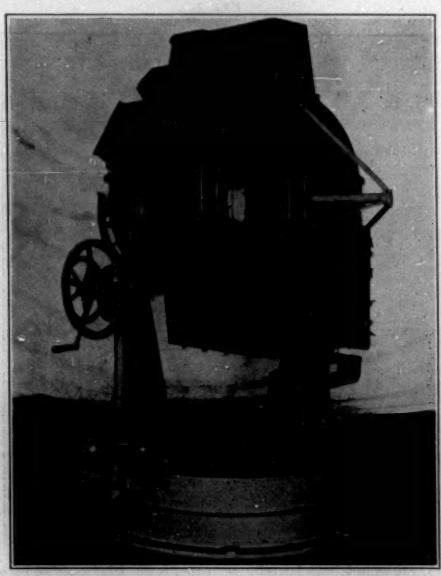
Sixty-inch, 150 ampere, high intensity arc, barrel type of searchlight, typical of design used for coast defense emplacements.

and immobile. The design was first modified to meet mobile army requirements. The heavy base (Fig. 2) was replaced by a four-wheeled carriage (Fig. 3). This was an important minor modification. It permitted manufacturers to supply practically standard equipment, for the production of which they had a full set of tools. One hundred and eighty (180) of these units were

ordered late in 1917. Shipments of them were started to France in the spring of 1918. They formed a portion of the searchlight equipment of the First and Second Armies, A. E. F., and made a splendid record on the Western Front.

5. The placing of 60-inch drum searchlights on wheeled bases

FIG. 2.



Thirty-six-inch, 150 ampere, high intensity arc, barrel type of searchlight, typical of the design formerly used in coast defense emplacements.

was considered at the time the 36-inch model was developed. The standard 60-inch drum, trunnions and yoke were, however, too heavy and tall to permit making them mobile by the substitution of a wheeled base for the standard stationary base. As a first solution the standard equipment was arranged as shown in Fig. 4. This was an assembly of available units in order to provide a semi-

portable equipment for immediate service in France. Only a few of these units were built, because they were relatively heavy and costly and could only be moved at relatively low speeds and then with difficulty. They illustrated, however, the tendency to promptly provide the American Expeditionary Forces in France with matériel required for military operations.

FIG. 3.

Thirty-six-inch, 150 ampere, high intensity arc, barrel searchlight, mounted on wheeled base and typical of the type used by the A. E. F. in France.

6. The problem was next presented to searchlight manufacturers. They studied it for a short time and then proposed building light-weight drums, supports and carriages. One manufacturer used aluminum in every practicable place. The result is shown in Fig. 5. The searchlight complete weighs 2300 pounds. It represents the practical limit of this method of design. It has an automatic mechanism and all of the other features of the 1917

model (Fig. 1), excepting distant electrical training control. However, it is infinitely more mobile. It is shown in Fig. 6, arranged for lorry transportation.

7. Another 1918 design of 60-inch light-weight drum is shown in Fig. 7. In this design new methods were devised for making and supporting the component parts. It weighed 2200 pounds. It had an automatic arc feeding and regulating mechan-

Fig. 4.

Sixty-inch, 150 ampere, high intensity arc, barrel type of searchlight and 125 volt 25 kw. gasoline-electric generating set, mounted on trailers, typifying equipment designed for mobile army.

ism and besides was equipped with a new design of distant electrical training control. It was in every way the equal of the 1917 model designed for fixed emplacements, in addition to which it was *mobile*.

8. About the time the design of the light-weight barrel searchlights was projected, a representative of the A. E. F. was returned to the United States. This officer was Major Richard Wheatly Lewis, Engineers, who, at that time, was a captain in the 56th Engineers. He was instructed by Lieut.-Colonel John C. Gotwals, Commanding Officer of the 56th Engineers, to con-

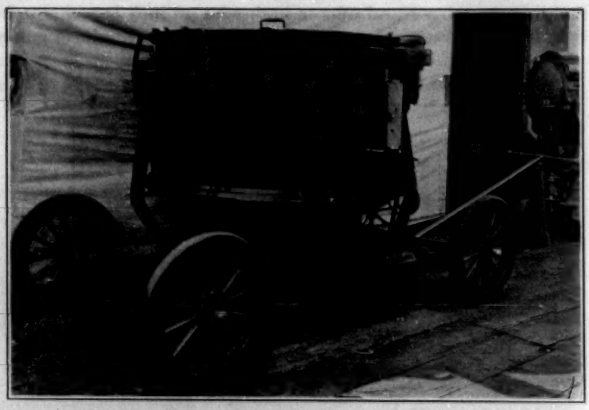
fer with the Engineer officers in the United States and to present to them the problems which had arisen in connection with the operation of searchlights in the field in France. Major Lewis

FIG. 5.

Sixty-inch, 150 ampere, high intensity arc, light weight barrel type of searchlight, on wheeled base, illustrating minimum practicable weight for this design.

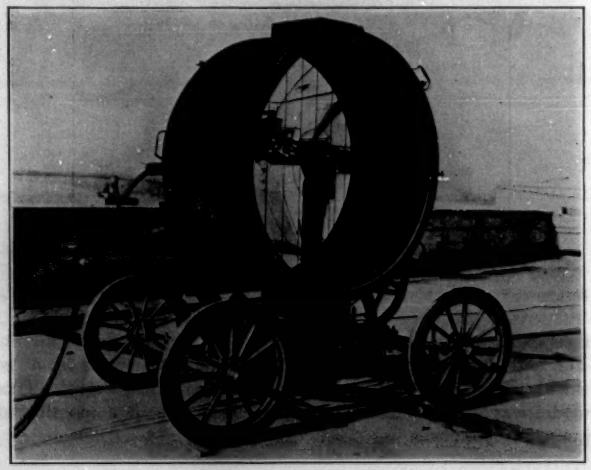
had exceptional opportunities for observing the requirements, and besides was gifted with a unique synthetical mind, which enabled him to make a very remarkable suggestion. In April, 1918, he sketched what has since been known as the open-type searchlight. In May, 1918, the first model was built at Ellington Field, Texas.

Fig. 6.



Sixty-inch, 150 ampere, high intensity, light weight barrel searchlight, arranged for lorry transportation.

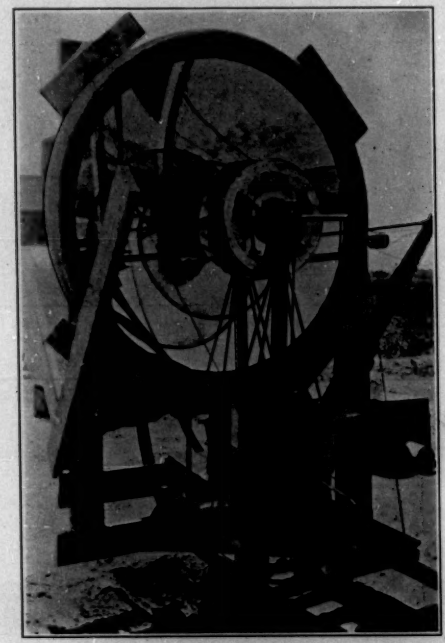
Fig. 7.



Sixty-inch, 150 ampere, high intensity arc, wheeled light weight, barrel searchlight, illustrating second design to give maximum power with minimum weight.

It was a 36-inch design. It is shown in Fig. 8. It consists essentially of the mirror and mirror back of a 36-inch barrel searchlight hung in trunnions, with the automatic high intensity

FIG. 8.



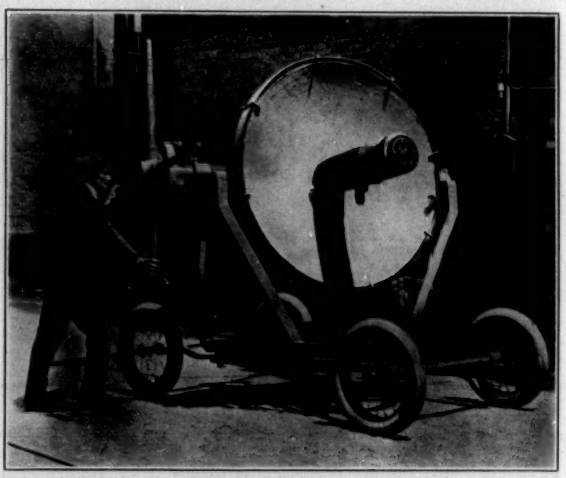
First model of open type searchlight. It has 36-inch glass mirror and 150 ampere high intensity arc mechanism.

mechanism of the same light supported in front of the mirror. The carbon points were protected from wind currents by a tin shield which, at the same time, minimized stray light. This model was operated at Ellington Field for about a month and proved very efficacious.

9. The suggestion of the open-type mounting was immediately followed by the presentation of the idea to searchlight manufacturers. They were requested to consider its possibilities and to immediately develop models which could be manufactured in quantity and shipped promptly to the A. E. F.

10. One of the first commercial developments of the open-

Fig. 9.



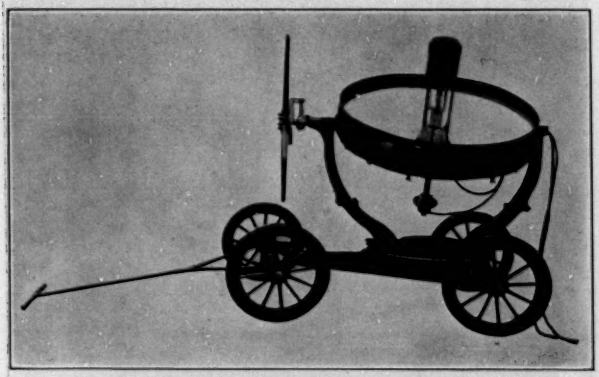
First commercial open type searchlight. It has 60-inch mirror and 200 ampere medium intensity arc mechanism.

type searchlight is shown in Fig. 9. It was designed and built about June 15, 1918. It was subjected to close scrutiny, which indicated a number of minor improvements. These had in view a reduction of weight, an increase in rigidity and an increase in mobility. The result of these suggestions was the design and building of the first practical commercial open-type searchlight which was exhibited June 28, 1918. It is shown in Fig. 10. The mounting consists essentially of a rigid triangular base, provided with axles and wheels. The turntable and yoke are mounted

above the triangle. The mirror ring and trunnions are set in the yoke. Ribs from the mirror ring to a central breech form a holder for the mechanism. The arc mechanism is of cartridge type and is held in the breech at a suitable position. The mirror is supported in the mirror ring in the usual fashion.

11. In order to facilitate production, representatives of the Army Engineers and the manufacturers met in Washington in the summer of 1918 and completed a so-called standard Army

FIG. 10.



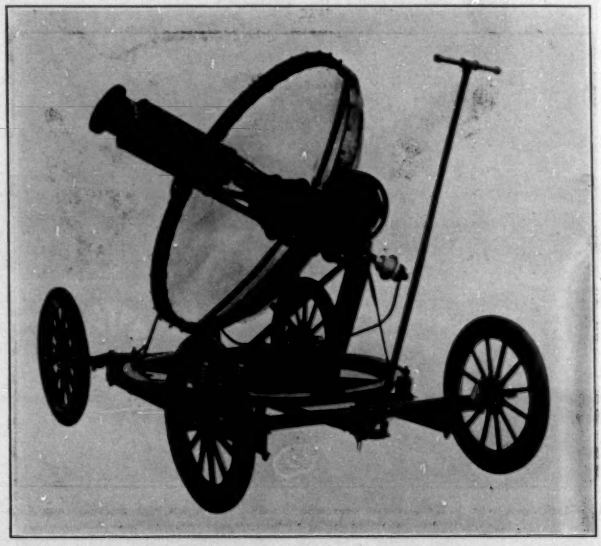
Second commercial design of open type searchlight. It has three point suspension, rigid frame carriage and stray light shield surrounding the mirror.

design of carriage and mounting. With minor modifications, a large quantity of these were built by the manufacturing companies. Representative types are shown in Figs. 11 and 12. They enabled standard running gear to be used. These could be obtained in quantity and thus permit rapid delivery. They used a relatively light-weight turntable, yoke, mirror ring and trunnions and were so designed as to permit of manual distant training.

12. Early experience with a few of the mountings shown in Figs. 11 and 12 indicated that a marked saving in weight could be effected if special parts, instead of standard parts, were used. Several models were designed and built. These are shown in

Figs. 13, 14 and 15. Complete with searchlights, they weigh less than 1000 pounds. They are so designed as to permit various portions to be readily removed. The running gear is easily taken off. The mechanism can be taken out of the breach by one man. The mirror ring with the mirror can be lifted out of the yoke

Fig. 11.



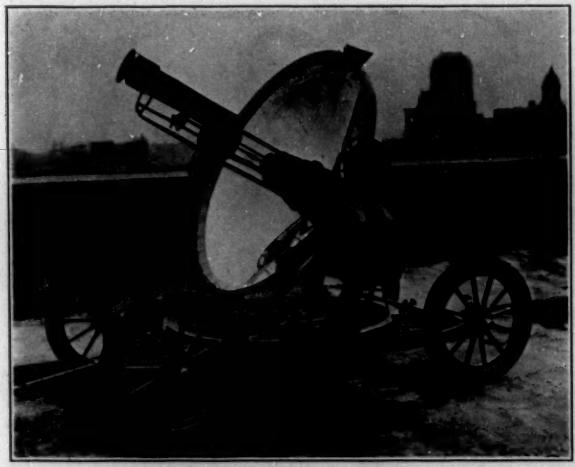
Sixty-inch open type Army design searchlight with 200 ampere, medium intensity arc mechanism, similar to design standardized and used by the A. E. F. in France.

by two men at the trunnions. The result has been the development of a very light-weight mounting, capable of being rolled over the ground to the point of emplacement and there rapidly dismantled, emplaced and assembled.

13. Another result of the intensive study of 60-inch wheeled mountings and litter mountings which have been described was the development of a very light weight, small diameter mirror

type of searchlight, mounted on a tripod. This was designed with a view of providing a very portable equipment, which could be placed in otherwise inaccessible places. For example, it is often advantageous to locate a searchlight on top of a tower or in a church belfry or in the top of a tree. The 60-inch designs are too heavy to permit of such installation. However, the

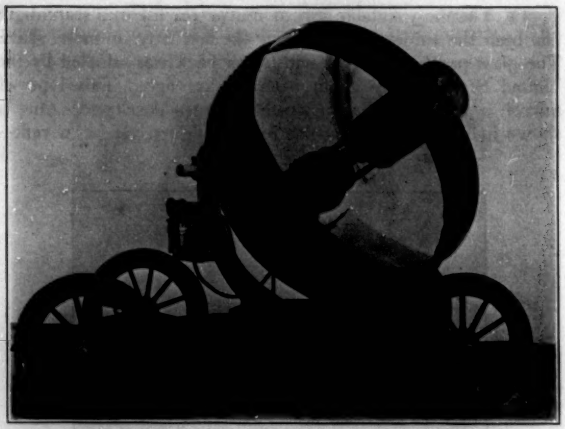
FIG. 12.



Sixty-inch open type Army design of searchlight, with 150 ampere high intensity arc lamp mechanism, typifying design used by A. E. F. in France.

30-inch designs, shown in Figs. 16 and 17, are admirably adapted for this sort of installation. They are each provided with 30-inch glass mirrors, hand-operated, high-intensity arc mechanisms and the usual complement of adjusting scales, stray light shields, finders, etc. They are unusually efficient at ranges up to 15,000 feet. The designs illustrated take the same sizes of carbons as do the 60-inch high-intensity designs and operate at the same current and voltage; that is, 150 ampères, 75 volts. They weigh only 225 pounds.

FIG. 13.



Late development of 60-inch open type searchlight, with 200 ampere medium intensity arc lamp mechanism, improved carriage, improved light shield on mirror and internal finder on mechanism.

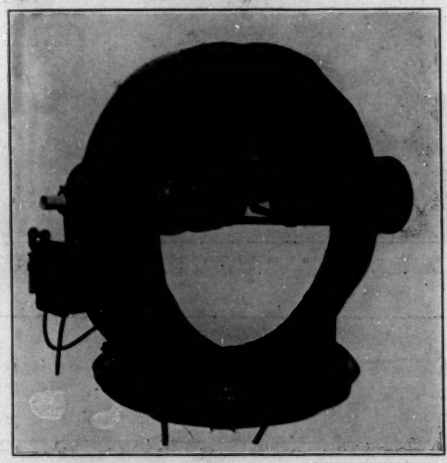
FIG. 14.

Early design of 500 ampere medium intensity arc lamp mechanism in open type searchlight.

MIRRORS.

14. The most suitable sort of mirror for use in a searchlight has been the subject of study for the last fifty or more years. The glass parabolic mirror with silver back was adopted by the United States Army about fifteen years ago. This type of mirror is the most efficient which has been developed. One is shown in Fig. 18 during a line test for figure. It has a reflec-

FIG. 15.

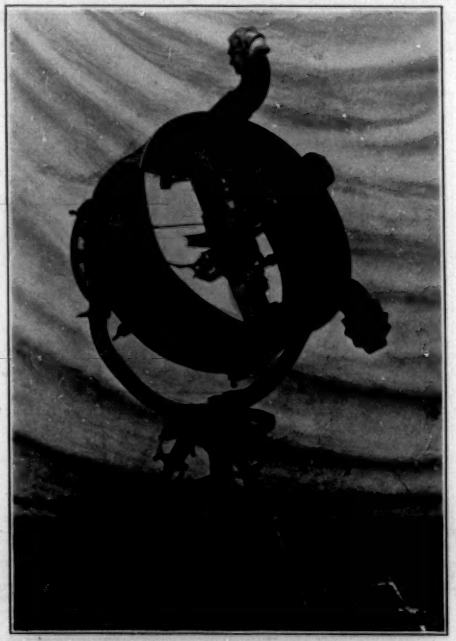


1920 design of open type searchlight, with 200 ampere medium intensity arc lamp mechanism, having internal finder. This equipment is typical of the design now being mounted on the portable towers.

tivity of about 95 per cent. and an almost perfect figure. It has, however, one very important limitation. Its manufacture requires from eight to fifteen weeks on account of the numerous and delicate processes through which it must go. It is also to a certain extent fragile, although a very wide experience indicates it to be very much less so than appearances would indicate. In fact, the records of the A. E. F. indicate only one mirror broken during transportation and only two mirrors broken by detonations.

15. The physical limitations in the production of parabolic glass mirrors resulted in a great deal of study being given to other methods of producing suitable searchlight mirrors. The

Fig. 16.

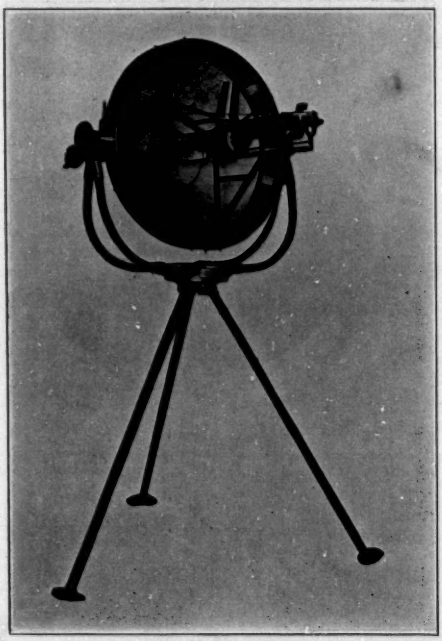


Thirty-inch open type searchlight with 150 ampere high intensity arc, hand feed mechanism, illustrating extremely light weight design.

literature on the subject was digested. Eminent authorities were consulted. Manufacturers were interested. As a result, a relatively new method of mirror manufacture was started. The glass portion of the silver-backed glass mirrors was used as a form. Silver was chemically deposited on it in the usual manner.

Next the silver coating was backed with electrolytically deposited copper or copper and nickel. Then the silver surface and its backing were lifted from the glass form. The initial experi-

FIG. 17.

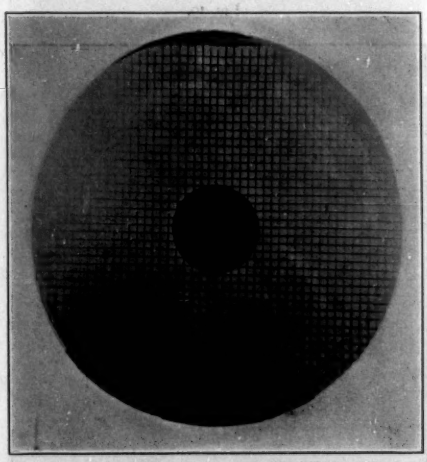


Another design of 30-inch open type searchlight with 150 ampere, high intensity arc, hand feed mechanism.

ments were unusually successful and gave great promise. Difficulty was experienced, however, in providing a suitable backing for the very thin film of silver. It was necessary that the backing be as rigid as glass, else the figure of the mirror would suffer. It was also necessary that the backing retain its exact shape and

not change due to temperature or moisture conditions. A great deal of experimental work was done, and there was developed prior to the November 11, 1918, armistice a method of manufacturing metal mirrors which enabled them to be produced at less than half the cost of glass mirrors and in about one-fifth the time. The metal mirrors had practically the same coefficient

FIG. 18.



Photograph taken of a parabolic glass mirror, showing the accuracy of its figure. The lines in the photograph are reflections from parallel lines on a large screen held in front of the mirror. The photograph was taken from a point just behind the screen, the camera lense being pointed at the mirror through a hole in the screen.

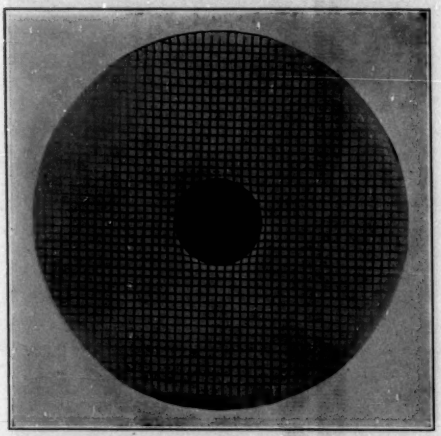
of reflectivity as the glass mirrors and practically as good a figure. The silver surface was protected by a suitable gum varnish which retained its protective powers without deterioration for about four to six months. At the end of this time it was necessary to remove it by a solvent and then replace it by a new coating. The process of removing and recoating is simple and, with a little care, can be accomplished in the field. It in no way affects the reflectivity of the surface. Types of metal mirrors

developed in accordance with this process are shown in Figs. 19, 20 and 21.

MECHANISMS.

16. The mechanisms used for pre-war searchlights were complicated and delicate affairs, weighing 100 pounds or more. A typical one is shown in Fig. 22. It is basically an automatic mechanism for maintaining the correct distance between the car-

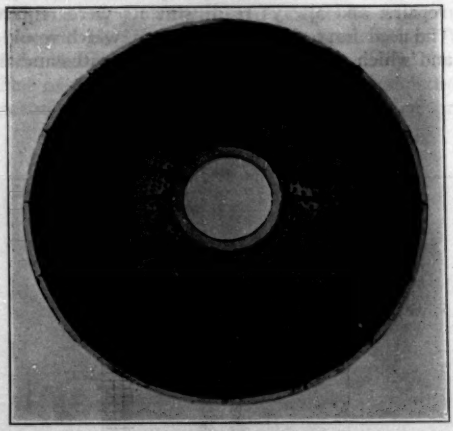
FIG. 19.



Reproduction of photograph illustrating line test of a silver metal mirror made by the deposition process and illustrating the accuracy of its figure.

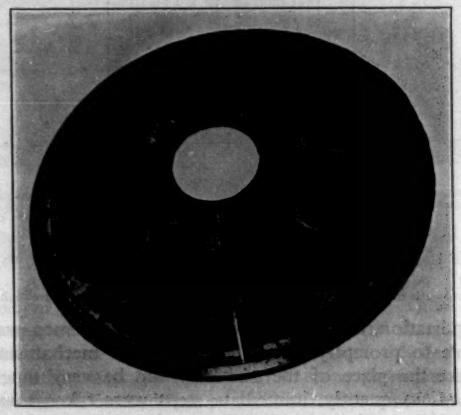
bons and between the positive carbon crater and the mirror and for feeding them as they are burned away. In addition, the mechanism is so designed that the positive carbon is continuously rotated. This is done in order to make the crater of uniform shape. The mechanism performed its functions relatively successful. On account of the many parts which it contained, however, it was not well suited for mobile searchlights. In transporting it from place to place, many of the small parts fell out of adjustment, so that after reaching its destination and

FIG. 20.



Ribbed sheet steel reinforcement for the cement backing of a metal mirror.

FIG. 21.

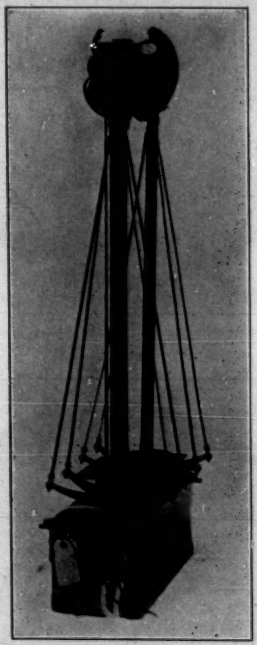


Spoke and rim design of reinforcement for a deposited silver metal mirror with copper nickel backing.

before it could be operated an inspection was necessary and frequently repairs, and always readjustments were required.

17. The need for a simpler mechanism, which would be more rugged and which would more successfully withstand the rigors

FIG. 22.



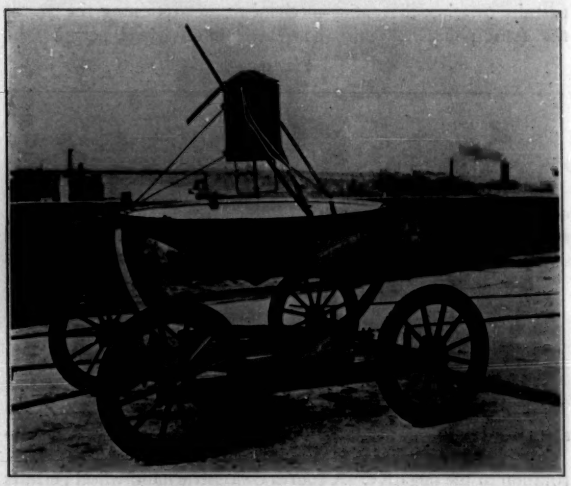
Automatic mechanism of 60-inch, 150 ampere high intensity arc searchlight.

of transportation, was soon evidenced. It was deemed practically impossible to promptly design an automatic mechanism which could take the place of the standard and be very much more rugged. Consequently, immediate steps were taken toward the design and production of a hand-fed mechanism. The design was

primarily based on the requirements of the open-type searchlight shown in Figs. 8 and 9. This utilized a cartridge type of mechanism which could be fitted into a breech block either from the rear or from the front.

18. One of the early designs contemplated supporting the entire mechanism from the mirrror ring by means of struts. A

Fig. 23.

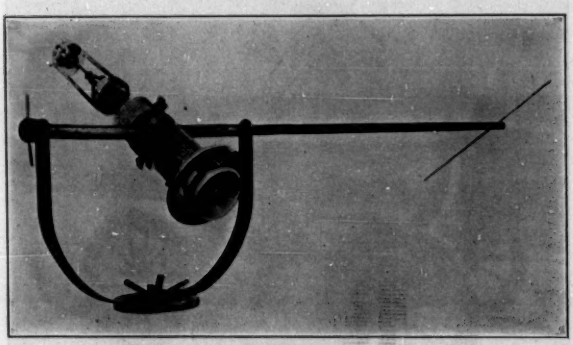


Mechanism and other details of an early design of 200 ampere, medium intensity arc mechanism for open type searchlight, showing hand feed and method of supporting mechanism from mirror ring.

sample of this mechanism, mounted in a searchlight, is shown in Fig. 23. Another design used the cartridge principle. It had all the principal parts located about a central axis. These were in turn connected to an aluminum casting which fitted into the breech block from behind. An early sample of this development is shown in Fig. 24. This presented so many good features, particularly ruggedness and few parts, that it was adopted as one of the standards. A few features of design were modified and the

rough edges polished off. A number of these units were then ordered for the use of the A. E. F. A typical one is shown in Fig. 25. It uses 28.5-mm. positive carbons and 16-mm. negative carbons. A current of 200 ampères at 65 volts produces in this mechanism what is known as a *medium intensity arc*. The entire control is from the rear of the searchlight. One hand wheel permits rotation of the entire mechanism, so as to adjust the arc to the correct focal point. A second concentric hand wheel permits rotating the entire mechanism, yet retaining the arc at the focal point. A third concentric hand wheel permits the

FIG. 24.



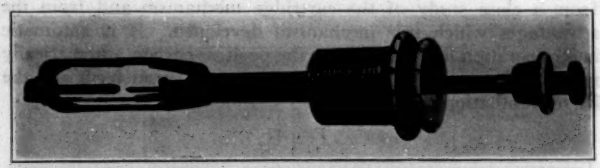
First design of cartridge type mechanism for 200 ampere medium intensity arc of open type searchlight.

rotation of the negative. A fourth concentric hand wheel permits feeding of the negative. A plug, concentric with the hand wheels, acts as a switch as well as a current terminal.

19. Another form of cartridge mechanism is shown in Fig. 26. It uses 16-mm. diameter positive carbons and 11-mm. diameter negative carbons. It produces a *high-intensity arc* with 150 ampères at 75 volts. Unlike the previous mechanism, this one is fitted into the breech block from the front of the mirror. The controls, however, are at the rear of the mirror. One handle rotates and feeds the positive. A second handle feeds the negative. A device is provided for giving small lateral adjustment to the mechanism so as to bring the arc into the axis of the mirror.

The arc is maintained at the focal point by suitable feeding of the positive and negative carbons. Two positions along the axis of the mirror are provided so as to accommodate metal or glass searchlight mirrors.

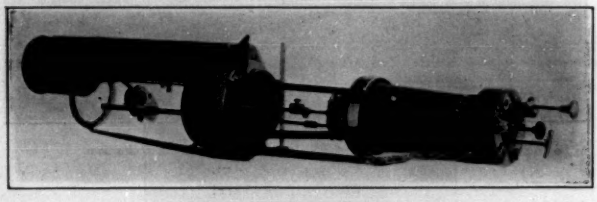
FIG. 25.



1918 design of 200 ampere medium intensity arc lamp mechanism, for 60-inch open type searchlight.

20. A further development of the cartridge searchlight mechanism has been in the direction of making the finder self-contained with it and providing the negative control with a flexible connection, so that the arc may be better guided with respect to the positive crater. A late design of such a mechanism is

FIG. 26.



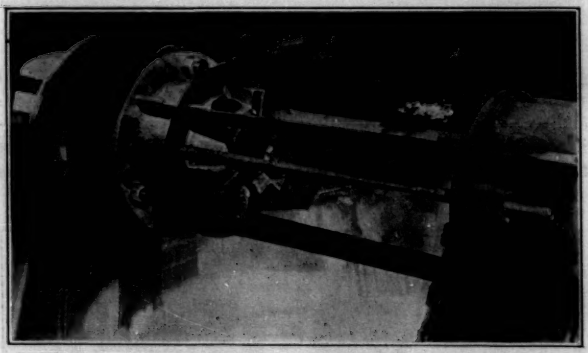
1918 design of 150 ampere, high intensity arc lamp mechanism, for 60-inch open type searchlight.

shown in Fig. 27. It has a self-contained finder, which is located very close to the control hand wheel. Otherwise, it is substanially the same as the cartridge mechanism shown in Fig. 25.

21. A radical redesign in mechanisms for barrel searchlights has recently been undertaken. One form of development has substituted aluminum in place of bronze or cast iron. In addition, the redesign has included making the pillar for supporting the carbons very much stiffer. As a result, the positive crater

is held rigidly in position. One form of such mechanism is shown in Fig. 28. It is automatic in operation. It has a single electric motor for operating the forced draft ventilation and the mechanism feeds. Another form of mechanism which differs radically from the preceding is shown in Fig. 29. It has resulted from a close study of the cartridge mechanism and from the advantages which this mechanism developed. It is automatic in its operation and besides has the positive carbon automatically rotated. It uses a single motor for the mechanism feeds and the barrel ventilation.

FIG. 27.



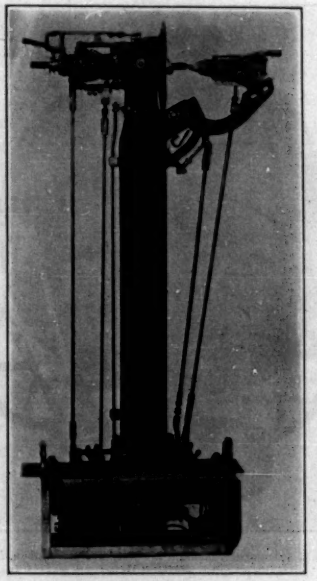
1919 design of internal finder for open type searchlight mechanism.

LIGHT SOURCES.

22. Light sources for searchlights have been the subject of a great deal of study. Flames, incandescent solids and electric arcs have been examined. The flames of all kinds are so large that they cannot readily be placed at the focus of the mirror and do not give a nice clean-cut beam of relatively small divergence. Besides, their temperature is low and the amount of light which they give per unit of energy input is relatively small. In addition, it is difficult to maintain them and they are very sensitive to air disturbances. Incandescent solids, particularly in the form of the incandescent or glow lamp, are very fascinating light sources

for a searchlight. They require no adjusting. They operate throughout their life with practically uniform brilliancy. They are easily replaceable. They are relatively rugged. However, they have the very grave objection that the most efficient designs are only about one-third as efficient as the high-intensity arcs,

Fig. 28.



1919 design of light weight mechanism for 150 ampere high intensity arc barrel type of searchlight.

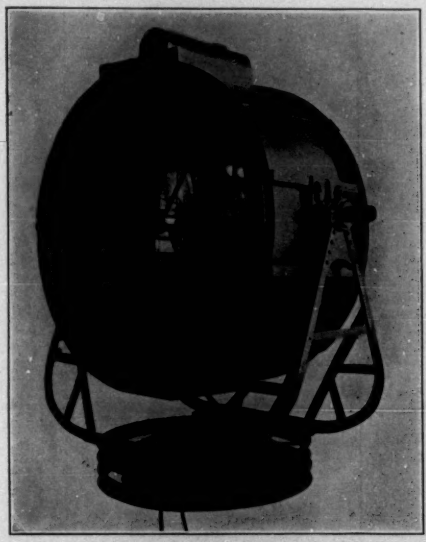
and besides, up to the present time, it has been impracticable to make them in commercial units larger than 3000 watts.

23. Electric arcs seem to have given the best kind of service for searchlights. They are relatively simple and enable a large flux of light to be concentrated in a relatively small area. As a result, an electric arc may be placed at or near the focus

of a reflector or mirror and produce, in combination with the mirror, a searchlight beam of relatively small divergence and high illumination.

24. Searchlight arcs may be divided into three classes, known, respectively, as low intensity, medium intensity and high intensity.

FIG. 29.



1919 cartridge design of 500 ampere, medium intensity arc mechanism, for light weight barrel searchlight.

The low-intensity arc is the ordinary one, such as was formerly used for street illumination. It operates with about 0.3 amp./sq. mm. of crater area. It gives a relatively yellow light and operates at a maximum temperature of about 3500° C. abs. Medium-intensity arcs have been a recent development. They are arcs taking practically the same electrodes as the low-intensity arcs, but with the current pushed up to the practical

limit of quiet operation. Such arcs operate with a current density of about 0.6 amp./sq. mm. and a maximum temperature of about 4500° C. abs. They give a brighter light than do the low-intensity arcs. They are distinctly more yellow and have in them more of the blue and violet, although this is not readily discernible.

25. A modification of the plain carbon arc is the so-called magnetically controlled arc. Various forms of the control have been devised and tried from time to time. The simplest form is one which carries current parallel to the carbons and produces a flux which steadies the arc stream. The arc with magnetic control is a bit brighter than the plain medium-intensity arc, but is not nearly so bright as the high-intensity arc. It operates at an approximate temperature of 4800° C. abs.

26. The high-intensity arcs differ from the low- and medium-intensity arcs in that the illumination comes from an incandescent globule of gas held in the crater (Fig. 30-B). This gas has a maximum temperature of about 5500° C. abs. The light given from a high-intensity arc is distinctly white, with a bluish tinge. It has remarkably great concentration of light flux, even when compared with the low-intensity and medium-intensity arcs. It represents the most efficient form of artificial light-producing source which is known.

27. The stability, steadiness and color of searchlight arcs are all of relatively great importance. Stability is given to an arc by a proper proportioning of the electrodes and by a suitable ballast resistance in series with the arc circuit. Steadiness is given by uniformity of flux in the neighborhood of the arc stream, homogeneity of the electrode materials and by a steady source of power supply. Color is primarily determined by the current density at which the carbons are operated or, in other words, the maximum temperature at which they are operated.

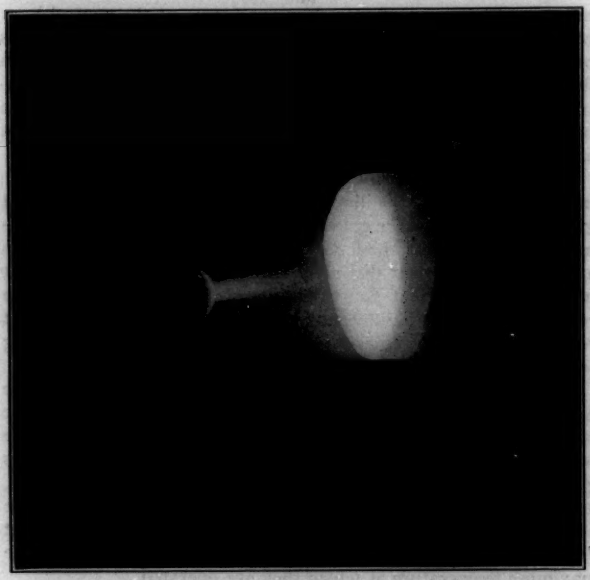
CARBONS.

29. Carbon has been found to be the most suitable material out of which to fashion the electrodes for searchlight arcs. This is due to its well-known high-temperature resisting qualities. Carbon for searchlight electrodes varies through a very wide range of characteristics. It may be hard or soft. It may be uniform in texture or mixed. It should preferably be of uniform

texture and either hard or soft, depending upon the type of arc which is to be maintained.

30. Medium-intensity and low-intensity arcs usually have electrodes with hard carbon shells and medium or soft carbon cores. The cores are provided in order to assist in centring

FIG. 30-A.



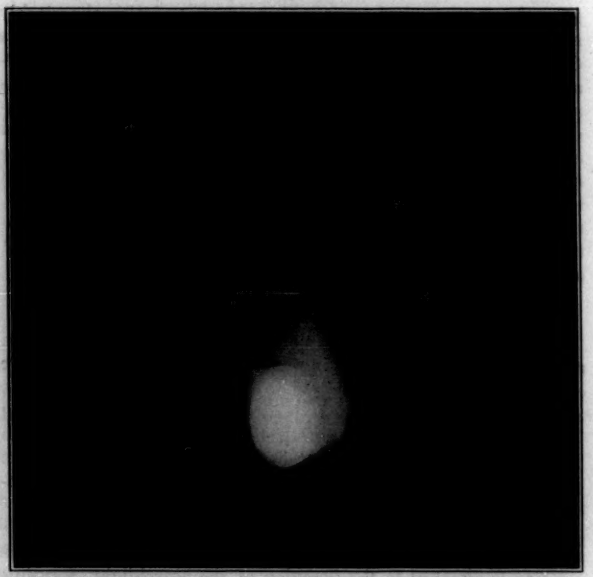
200 ampere, medium intensity arc, typical of those used in open type searchlights. Arc uses 28.5 mm. diameter positive carbon and 16 mm. diameter negative carbon.

the arc and forming the crater. The ratio between shell diameter and core diameter varies, depending on the current density of the crater. For low-intensity and medium-intensity arcs, it may be as high as 5 to 1. For high-intensity arcs, it depends on the character of the core material. High-intensity arcs are usually maintained between carbon electrodes provided with cores of

special chemicals. These use various compounds of the cerium family or group. The composition of the core assists in forming the gas globule which, when heated to incandescence, gives the high-intensity arc characteristic.

31. Low-intensity and medium-intensity carbons may or may

Fig. 30-B.



150 ampere, high intensity arc, typical of those used in open type and barrel type of searchlights. Arc uses 16 mm. diameter positive carbon and 11 mm. diameter negative carbon.

not be copper plated, depending on the form of electrode core and the current supplied to them. Where the carbons are held at the ends and where the current is high, copper plating is necessary in order to carry the current along the carbon without heating it and causing spindling.

32. The crater formed in a carbon is important with regard

to the light-giving power of the arc established. The crater of low-intensity and medium-intensity arcs should be preferably dish-shaped, while the crater of high-intensity arcs should be preferably cup-shaped. The material used in the manufacture of carbons and the skill displayed are of prime importance in kind of crater obtained.

33. Electrodes are usually made by mixing pure carbon or graphite with lampblack or some other binder, and after thoroughly mixing them, forcing a certain portion of the mixture through a die. The dies are quite ingenious. They are so arranged as to permit the extrusion of cylinders with hollow centres. These cylinders are then placed in cast-iron boxes, which are packed with powdered graphite and then heated in order to distill off the fluid components of the binder. The heating is preferably done in electric furnaces, so that the heat may be under control at all times and a uniform product produced. After baking or firing, the electrodes are "cored." This is done by squirting the core material into the shell. Next, the electrodes are tested, assorted and packed for shipment in moisture-proof containers.

TRAINING CONTROLS.

34. The movement of searchlights in aizmuth and elevation requires some form of training control. Some searchlights are operated by personnel adjacent to them. Other searchlights require training from remote points. It is with the training from remote points that most of the difficulty is experienced. For this service two classes of training control have been devised. They are known respectively as mechanical distant-training controls and electrical distant-training controls.

35. Mechanical distant-training controls are exemplified by pipe controls and cable controls. In the pipe control, a piece of gas pipe is attached to the trunnion of the searchlight, forming an elongation thereof. At the other end of the gas pipe is placed a tee, through which two handles are threaded. The whole forms a means by which an operator may rotate the searchlight in azimuth by walking around with it and may move the searchlight in elevation by twisting on the training control pipe. The scheme was developed by the British Expeditionary Forces in France and was used almost exclusively by them in the 1914–1918 operations in France. It is simple and easily operated. It permits the

searchlight pointer to quickly place the searchlight in any desired direction and at the same time to slowly train it in following a plane which has been picked up. It is limited, however, by the fact that the operator must of necessity be close to the searchlight, since pipe-training controls of this design cannot be more than about 12 or 15 feet long. It is illustrated in Fig. 31.

36. Cable training controls have been tried but have not been entirely successful. They have followed in general the designs used for many years on railway semaphore signalling. They

Fig. 31.

Sixty-inch, 150 ampere, high intensity arc, barrel type of searchlight and three meter paraboloid in an emplacement on the Meuse Front, showing pipe control for training searchlight.

have the very grave objection that they are not readily installed in temporary positions and that there is a great deal of back-lash giving inaccurate control. They have not been used to any great extent.

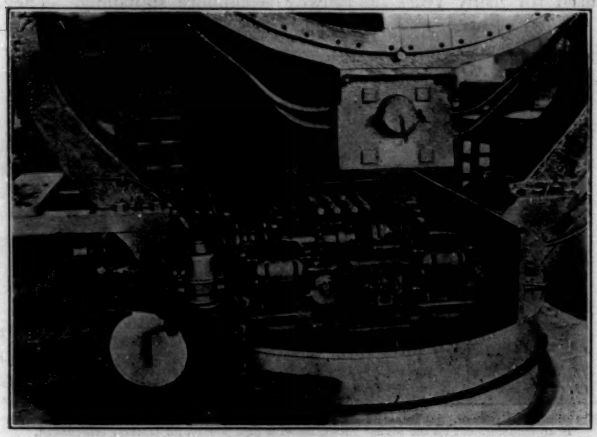
37. Electrical distant-training controls in wide variety have been used with searchlights for a number of years. Some of them have been successful. None of them, however, are suitable for field service, such as permitted the successful application of the British pipe control.

38. Electrical distant-training control systems may be divided in accordance with the system used for moving the searchlight. These may use series dc motors, shunt dc motors, synchronous ac

motors, asynchronous ac motors or solenoids. In addition, there may be combined with any one or more of these some form of hydraulic speed gear. All of these schemes use some form of relay for controlling the main training motor, and it is on account of this intermediary that many of them have been unsuccessful.

39. The requirements for a distant electrical training control are relatively severe. The control must be simple in construction,

FIG. 32.



Mechanism details of distant electrical control for 60-inch barrel type of searchlight.

require a minimum number of electric wires, be light in weight and preferably be so arranged that a position indicater may be added without too great complication. The training requires a torque of from 75 to 300 foot-pounds, depending upon the size and weight of the searchlight. The control must be so arranged that the searchlight may be revolved at a maximum speed of four to five rpm. or at a minimum speed of 1/100 of an rpm. in both azimuth and elevation. The control mechanism must also be of such nature that the searchlight may be operated from a distance of 200 yards, as well as from a distance of 10,000 yards. The operation of the field equipment is usually at points from 200 to

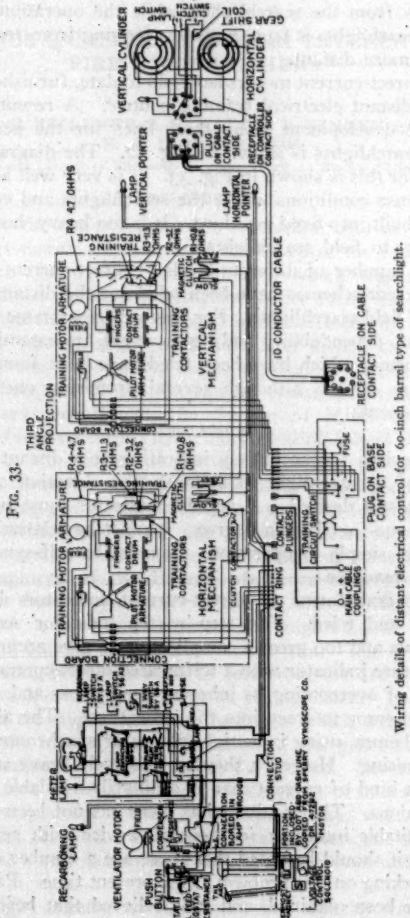


Fig. 33.—Wiring details of distant electrical control for 60-inch barrel type of searchlight.

300 yards from the searchlights, while the operation of coast-defense searchlights is from positions ranging from 1000 to 6000 yards or more distant.

40. Direct-current motors have, up to date, furnished the best form of distant electrical training control. A recent and very successful development along these lines for the heavy coast-defense searchlights is shown in Fig. 32. The diagram of connections for this is shown in Fig. 33. It is very well adapted for coast-defense conditions where the searchlights and control stations are built into fixed positions. It is too heavy, however, for application to field searchlights.

41. A number of different kinds of direct-current and alternating-current schemes have been tried for the distant electrical control of field searchlights. For this service extreme simplicity, ruggedness, dependability and light weight are essential. None of the schemes which have been tried have been found successful for this service, although several promising ones are now in development.

INDICATORS.

42. Devices for accurately indicating at a distant point the position of a searchlight in azimuth and elevation are among the things still desired. A suitable indicator must be accurate to within one-fourth of a degree. It must be relatively light in weight and simple in operation. It must be self-synchronizing and easily readable.

43. Several forms of direct-current indicators have been developed and tried. The step-by-step indicator requires too many points and too great a complication to give accuracy. The iron armature indicator with a trifurcated direct-current field has no means of overcoming its inherent energy loss and, therefore, permits an error to creep into the indications. The alternating-current schemes, using induction motors or synchronous motors, seem promising. However, they are relatively heavy and require a different kind of current than is ordinarily available at searchlight positions. The result is that there has not been yet developed a suitable indicator for general service with searchlights. However, it should be noted that there are a number of investigators working on this problem at the present time. Partial solutions have been obtained, and it is believed that before long a suitable indicator will be available.

(To be concluded.)

POISONOUS GASES FROM CARBON TETRACHLORIDE FIRE EXTINGUISHERS.*

BY

A. C. FIELDNER, S. H. KATZ, S. P. KINNEY and E. S. LONGFELLOW.

Research Laboratory, Pittsburgh Experiment Station. Bureau of Mines.

INTRODUCTION.

DURING the construction of a submarine boat at the Navy Yard, Portsmouth, N. H., in August, 1919, an incipient fire occurred in one of the compartments, which was small and closely confined. A carbon tetrachloride fire extinguisher put out the blaze, but the men who used it were overcome by the fumes which they inhaled, and several days later died. They had the usual symptoms of poisoning due to a pulmonary, irritant gas.

At the request of the Bureau of Construction and Repair of the Navy Department, the Bureau of Mines investigated the effect of heat on carbon tetrachloride extinguishers with special reference to the nature of the decomposition products. The Pittsburgh Experiment Station has particularly good facilities for conducting gas investigations, and was also interested in the same subject in view of the use of carbon tetrachloride extinguishers in small rooms in mines for combating mine fires.

An employee of the Bureau of Mines suffered a similar though not fatal experience. While he was driving an automobile truck, a fire burst out under the engine hood. The auto was stopped but the engine continued to run. The driver stood on the running-board about three feet from the fire and applied carbon tetrachloride liquid from an extinguisher. The fire was put out but the engine fan blew the fumes which were generated back into the man's face. Inhalation of the gases caused him to lose consciousness and he fell to the ground. Several minutes elapsed before he was revived. A soreness of the respiratory system remained for weeks, then passed away, and no serious consequences resulted. This incident, and others not cited, show that there is a real danger in breathing these fumes under certain conditions at least.

A gastight chamber of 1000 cubic feet capacity was used for the first experiments with the carbon tetrachloride fire-extin-

* Communicated by the Director of the Bureau of Mines.

guisher liquids. Confirming experiments were made with carbon tetrachloride liquids, vaporized in air and passed through an electric-tube furnace of regulated temperature. The latter experiments substantiated the results obtained with actual fire in the chamber.

Phosgene, one of the most poisonous gases used in warfare, was found; also chlorine, another very poisonous gas; hydrogen chloride, which is less poisonous but is irritating to the mucous membrane; and the vapor of carbon tetrachloride itself, which is a dangerous anæsthetic. As a result of the experiments, it is recommended that carbon tetrachloride extinguishers be not used on fires in confined spaces by persons who are not protected from the gases arising, or who are unable to hold their breath and get away from the immediate vicinity of the fire at once after applying the extinguisher. The army type of gas mask affords good protection from the products of carbon tetrachloride decomposed by fires and its use is recommended for the purpose.

It is not the intention of this paper to discourage the use of carbon tetrachloride fire extinguishers, which are very effective for stopping incipient fires, because in most cases, ventilation or the large amount of air usually present, prevents the formation of dangerous concentrations of gas. Also, the operator can nearly always escape easily and quickly from the vicinity of the gas when he knows he should do so. Rather the purpose is to show the danger of using such extinguishers in small, unventilated places where escape is impossible.

PREVIOUS INVESTIGATIONS.

In 1868 Schutzenberger[1] found that phosgene was produced from carbon tetrachloride by passing the vapor, mixed with carbon dioxide, over pumice heated to 350–400° Centigrade. The probable reaction is

$$CCl_4 + CO_2 = 2COCl_2 \qquad (1)$$

Later he found that at temperature of a water bath phosgene was formed from carbon tetrachloride with oxygen supplied by sulfur trioxide[2] according to the equation

$$CCl_4 + 2SO_3 = COCl_2 + S_2O_5Cl_2 \qquad (2)$$

[1] Schutzenberger. P., Sus quelques reactions donnant lieu à la formation de l'oxychlorure de carbone; *Compt. Rend.*, vol. lxvi, 1868, pp. 747–8.

[2] Schutzenberger, P., Über die Einwirkung des Schwefelsaure-Anhydrids auf Kohlenstoffsuperchloride; *Ann. der Chem.*, vol. cliv, 1870, pp. 375–6.

Goldschmidt[3] found that carbon tetrachloride heated to 250° Centigrade in a sealed tube with a large amount of water, yielded carbon dioxide and hydrogen chloride. The equation probably is

$$CCl_4 + 2H_2O = CO_2 + 4HCl \quad (3)$$

With a small amount of water, phosgene was formed. The equation for this is probably

$$CCl_4 + H_2O = COCl_2 + 2HCl \quad (4)$$

Many other oxides react with carbon tetrachloride when heated with production of phosgene as found by Camboulives.[4] Silicon dioxide is an exception. Iron oxide reacted at 245° Centigrade. The reaction is probably

$$3CCl_4 + Fe_2O_3 = 3COCl_2 + 2FeCl_3 \quad (5)$$

Carbon tetrachloride passed through a glowing tube decomposes, according to Beilstein,[5] as expressed by the equations

$$2\,CCl_4 + \text{heat} = C_2Cl_4 + 2Cl_2 \quad (6)$$

$$2\,CCl_4 + \text{heat} = C_2Cl_6 + Cl_2 \quad (7)$$

That there is danger from gases arising from carbon tetrachloride fire-extinguisher liquids has been recognized by the trade. In a folder descriptive of hand fire extinguishers, the Fire Extinguisher Exchange, Cleveland, Ohio, states: "Carbon tetrachloride, the base of the liquid used in the one-quart extinguishers, strongly resembles chloroform in its physiological action; it is not now used as an anæsthetic as several deaths are laid to its charge. Under heat it gives off chlorine gas. Its use is dangerous in confined spaces."

CHEMICAL EXAMINATION OF THE FIRE-EXTINGUISHER LIQUIDS.

Commercial carbon tetrachloride and three extinguisher liquids produced by manufacturers were used in the experiments. Qualitative tests for carbon bisulfide and chloroform gave the following results:

[3] Goldschmidt, H., Über die Einwirkung von molecularem Silber auf die Kohlenstoffchloride; *Ber. Deut. Chem. Gesell.*, vol. xiv, 1881, pp. 927–30.

[4] Camboulives, P., Action des vapeurs de tetrachlorure de carbone sur les anhydrides et les oxydes; *Compt. Rend.*, vol. cl. 1910, pp. 175–7.

[5] Beilstein, F., Handbuch der organischen chemie; vol. i, third edition, 1893, p. 146.

Kind of Liquid	Presence of Carbon Bisulfide	Presence of Chloroform
Commercial Carbon Tetrachloride	Present	Absent
Extinguisher Liquid No. 1	Present	Present
Extinguisher Liquid No. 2	Present	Present
Extinguisher Liquid No. 3	Present	Present

Analytical distillation of the liquids gave the results in Table I, determined by Dr. E. W. Dean, of the Bureau of Mines Petroleum Laboratory.

TABLE I.

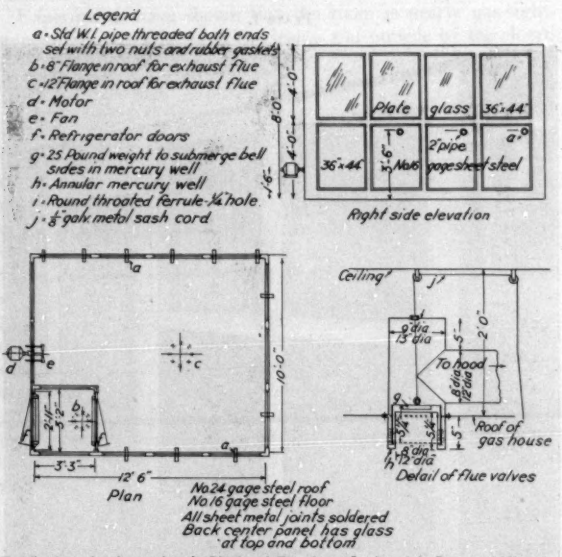
Results of Distillation of Carbon Tetrachloride Fire Extinguisher Liquids. 200 c.c. Distilled in a 6-inch Hempel Flask.

Amount distilled, per cent.	Commercial carbon tetrachloride. Barometer 739 mm.		Liquid No. 1 Barometer 730 mm.		Liquid No. 2 Barometer 743 mm.		Liquid No. 3 Barometer 738 mm.	
	Temp. ° C.	Sp. Gr.	Temp. ° C.	Sp. Gr. at 15 ° C.	Temp. ° C.	Sp. Gr. at 15° C.	Temp. ° C.	Sp. Gr. at 15° C.
First drop	67.0	.....	54	.....	54	.....	60	.....
1	71.0	.....	68	.....	69	.....	62	.....
2	72.0	.....	69	.....	70	.....	71	.....
10	74.3	1.599	71	1.567	71.5	1.564	71	1.570
20	74.8	1.596	71.5	1.579	72	1.580	71.5	1.584
30	75.0	1.600	72	1.583	73	1.585	72.0	1.584
40	75.1	1.600	72.5	1.588	73	1.588	72.5	1.587
50	75.3	1.603	73	1.591	73.5	1.593	73.0	1.588
60	75.3	1.603	73	1.591	74	1.595	73.5	1.590
70	75.4	1.603	73.7	1.596	74.5	1.598	74.0	1.597
80	75.5	1.604	74	1.598	75	1.601	74.5	1.597
90	75.5	1.606	74.3	1.601	75.5	1.602	75.5	1.599
95	75.5	1.606	74.5	1.603	76	1.603	75.5	1.601
Dry point	75.5	.....	74.5	.....	76	.....	.....	.....
Distilled...	97.1 percent.	.....	97.5 percent.	.....	95 percent.	.....	.....	95 percent.
Residue...	1.3 percent.	.....	1.6 percent.	.....	4.5 percent.	.897	.....	2.5 percent.
REMARKS..	First distillate gave odor of carbon bisulfide.		First distillate smelled of chloroform.		First distillate smelled of carbon bisulfide. Residue smelled of kerosene and was inflammable.		First distillate smelled of chloroform. Residue smelled of turpentine, but consisted of a tarry mass which decomposed by the heating.	

From the results of Table I, it appears that the first of the commercial extinguisher liquids was carbon tetrachloride with an admixture of chloroform to prevent freezing. Number 2 was

a mixture of carbon tetrachloride and a high-boiling petroleum distillate, added for the same purpose. Number 3 was a mixture of carbon tetrachloride with chloroform and turpentine. The purpose of the turpentine was to prevent escape of poisonous gases, such as chlorine, from the liquids when heated, but, as will

FIG. 1.


Legend
a - Std W.I. pipe threaded both ends set with two nuts and rubber gaskets
b - 8" Flange in roof for exhaust flue
c - 12" Flange in roof for exhaust flue
d - Motor
e - Fan
f - Refrigerator doors
g - 25 Pound weight to submerge bell sides in mercury well
h - Annular mercury well
i - Round throated ferrule-¼" hole
j - ⅛" galv. metal sash cord
Plate glass
36"×44"
2" pipe
No 16 gage sheet steel
Right side elevation
Plan
12' 6"
No 24 gage steel roof
No 16 gage steel floor
All sheet metal joints soldered
Back center panel has glass at top and bottom
Ceiling
To hood
Roof of gas house
Detail of flue valves

Details of gas chamber used at the Pittsburgh Experiment Station of the Bureau of Mines for experimental purposes.

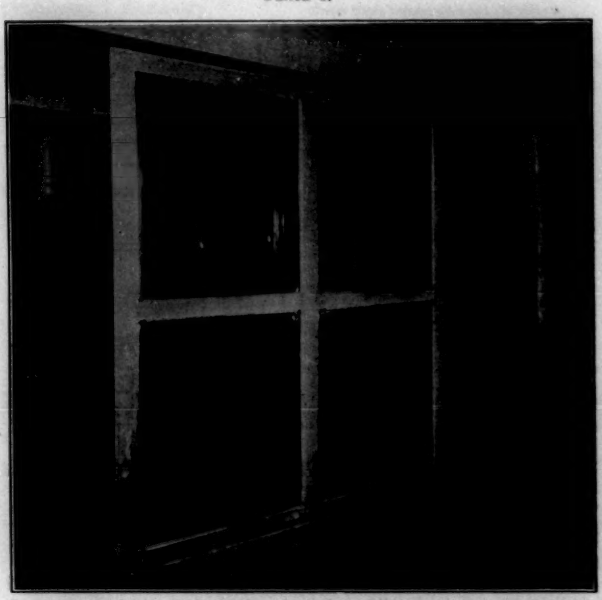
be shown later, it failed to do so. The carbon bisulfide found existed as impurity in the original carbon tetrachloride used to make the liquids.

EXPERIMENTS WITH FIRES IN THE CLOSED ROOM.

Apparatus and Procedure.—In Fig. 1, there are shown the details of the room or gas chamber used at the Pittsburgh Experiment Station of the Bureau of Mines for experimental pur-

poses. Plate I is a photograph of the chamber. The floor, walls and ceiling are constructed entirely of sheet metal. The windows are of glass, and the doors of wood, such as are made for large refrigerators. They are lined on the inside with sheet metal. Their edges are bordered with rubber; handles, made to exert a clamping effect, fasten the doors tightly against their jams.

PLATE I.



Gas chamber used at the Pittsburgh Experiment Station of the Bureau of Mines for experimental purposes.

All metal joints are soldered. The glass windows are cemented in the metal sash with a putty containing linseed oil and red lead, so the glass to metal joints are airtight. Special valves are set in the roof for connecting the room with a flue leading to an exhaust fan. The valve consists of a sheet-iron bell suspended

in a tube of slightly larger diameter. At the bottom of the tube, inside, is an annular space containing mercury. When the bell is seated in the annular space, the mercury seal makes the valve gas-tight. A chain attached to the bell runs over pulleys to a point where it may be reached by one on the outside of the chamber. Raising the bell into a closed space above a T in the pipe causes the gases in the chamber to be sucked out.

Experiments have shown that the room is nearly gas-tight. Interchange of gas between the inside and outside of the closed chamber amounts to less than 10 per cent. of the chamber volume per 24 hours.

To determine the behavior of both commercial carbon tetrachloride and the extinguisher liquids as regards breaking up and the nature of the gases given off when the liquid is put on a fire, experiments were made with small fires of excelsior and other inflammable material in the 1000 cu.-ft. chamber. Other experiments were made in the same chamber, in which the extinguisher liquids were poured upon red-hot iron, as it was thought that in the Portsmouth accident, liquid was possibly squirted upon an electric arc or hot metal that was being welded. A six-inch channel iron was heated to bright cherry red over a length of two feet. It was then quickly placed near the floor of the chamber, and the contents of a quart fire extinguisher steadily sprayed or poured upon it. The operator of the fire extinguisher wore a gas mask or one-half-hour breathing apparatus. After emptying the extinguisher on the iron or extinguishing the fire, the fan was started and samples of gas were taken for analysis as soon as the concentration became uniform.

Results of Experiments.—The results of the experiments are given in Table II.

Reference to the table shows that in all experiments the atmosphere created by using the fire extinguisher was dangerous. A rather surprising result of this investigation was the fact that the poisonous gas, phosgene, was liberated in every experiment, and in all cases in toxic quantities.

Experiment No. 1, in which 500 c.c. of carbon tetrachloride was poured on a red-hot, four-inch "I" beam, showed 168 parts per million of phosgene in the chamber atmosphere of 1000 cubic feet. This is a fatal concentration. Twenty-five parts per million will kill a man after breathing for half an hour; five parts per

TABLE II.

Results of Experiments with Heated Carbon Tetrachloride Fire Extinguisher Liquids in the Closed Chamber.

Experiment No.	Liquid used	Volume of liquid used c.c.	Source of heat	Estimated temp. ° C.	Results of analyses								Color of smoke
					CCl_4 P. P. M.	HCl P. P. M.	$COCl_2$ P. P. M.	Cl_2 P. P. M.	CO per cent.	CO_2 per cent.	O_2 per cent.	N_2 per cent.	
1	Com'l. CCl_4	800	4 inch "I" beam	825	4350	144	168	0	.00	.03	20.51	79.46	Yellow like chlorine (1)
2	Ditto	1000	6 in. channel	600	5850	...	80	23	.00	.4	20.3	79.3	Ditto (2)
3	Ditto	1000	Excelsior fire	...	5130	110	60	0	.41	3.49	16.59	79.39 CH_4.12	Red-brown, nearly black
4	No. 1	1000	Ditto	...	4970	82	15	0	.17	1.22	19.70	78.68 CH_4.17	Ditto (3)
5	No. 2	300	Ditto	...	2000	65	19	0	.22	.81	19.87	79.06 H_2.04	Ditto (4)
6	No. 1	400	6 inch channel	825	2607	60	30	10	.16	.31	20.68	78.84 H_2.01	Yellow like chlorine (5)
7	No. 2	1000	6 inch channel plus 4" "I" beam	950	2078	236	42	0	.22	.36	20.52	78.90	Black (6)

REMARKS:

(1) Odor of CCl_4 and HCl was noticed.
(2) Phosgene could be detected by odor.
(3) Could detect HCl and $COCl_2$ by odor.
(4) Could detect HCl and $COCl_2$ by odor.
(5) Could detect HCl and $COCl_2$ by odor.
(6) Liquid burned on iron with a flickering flame.

million produce coughing and irritation, and are dangerous after a time.

Chlorine was not found as a decomposition product in most of the experiments. Experiments Nos. 2 and 6 show some chlorine—not enough to be considered very dangerous, since in equal concentrations, it is somewhat less poisonous than the phosgene. However, 23 parts per million are exceedingly irritating and breathing it would produce bad effects. It is possible that some chlorine was absorbed by the asphalt paint on the chamber.

Small quantities of carbon monoxide were given off in most of the experiments, both with fires and with heated iron. The larger quantity was found with the excelsior fire. That evolved from the liquids on iron would produce headache and nausea by itself in a short time. The hydrochloric acid gas was present in quantity sufficient to be very irritating. Carbon tetrachloride vaporized to concentrations ranging from .2 to .6 per cent., or 2000 to 6000 parts per million. This concentration is not considered enough to produce anæsthesia in a short time. However, if the chamber volume were much smaller, there would undoubtedly be concentration of carbon tetrachloride vapor itself high enough to produce anæsthesia, and men would very quickly become unconscious. After this, the phosgene present would produce effects in the lungs and respiratory system that would surely prove fatal.

When commercial carbon tetrachloride is poured upon red-hot iron, it produces a yellowish smoke that looks much as though chlorine were one of the decomposition products. However, this is not the cause, and no chlorine was found—either by chemical test or odor—except in Experiments 2 and 6.

The predominating odor was carbon tetrachloride itself, phosgene, and hydrochloric acid. The yellowish color was found to be due to iron chloride formed by interaction between the hot iron and carbon tetrachloride. The iron chloride is vaporized, then reacts with the moisture in the air, hydrolizes, and forms hydrochloric acid and iron oxide. Liquid No. 1 gives the same sort of smoke as commercial carbon tetrachloride, while Liquid No. 2 gives a black smoke, due apparently to particles of carbon formed by decomposition of the kerosene or other petroleum oil that is put in this extinguisher to lower the freezing point.

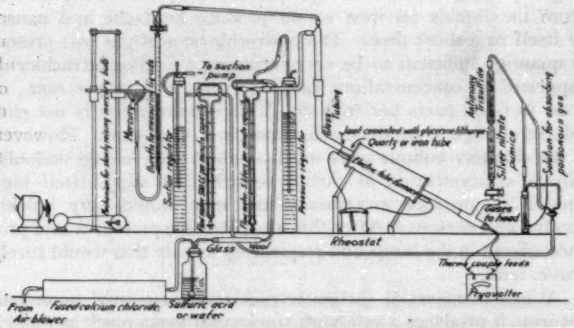
It was, of course, impossible for a man to take even one

breath of the atmosphere created in the gas chamber, while spraying the extinguisher on hot iron or burning excelsior.

EXPERIMENTS WITH HEATED TUBES.

The experiments in the closed room gave results which simulate the action of carbon tetrachloride liquids in actual use. But the nature of the reaction which occurs could not be studied readily in such experiments because of the impossibility of controlling some of the factors, such as temperature and humidity, which undoubtedly influence the decomposition. For that reason,

FIG. 2.



Apparatus for studying decomposition of carbon tetrachloride liquids in heated tubes.

other experiments were arranged with apparatus in which the conditions could be accurately controlled.

Apparatus and Procedure.—Figure 2 shows the apparatus diagrammatically. Air was passed at a uniform rate of 5 litres per minute through an electrically-heated tube furnace. The liquids being tested were added to the air stream in fluid form, at a uniform, measured rate, by means of a mechanism which continuously raised a mercury leveling bulb connected to a burette. As the mercury entered the burette, it displaced carbon tetrachloride liquid which ran into the tube carrying the air current. The liquid all evaporated into the air stream before the hot parts of the furnace were reached. Temperature at the centre of the furnace was measured by means of a platinum, platinum-rhodium

thermocouple and pyrovolter. The temperature through the furnace was of course not uniform, because the air absorbed some heat at the entrance. The temperature at the centre may be considered an average.

Samples were taken of the mixtures of gases which passed out of the heated tube. The volume of the samples of gas used for analysis was determined by means of a flowmeter of 500 c.c. per minute capacity. Various absorbents for the different gaseous constituents to be determined were placed between the main gas stream and the sample flowmeter.

Experiments were made at 600° and 800° Centigrade, with humid and dry air and with heated tubes of iron and of quartz.

The first experiments were made with chemically-pure carbon tetrachloride to secure comparative results under the different conditions of experiments, as regards temperature, humidity, and tube material. After these experiments, the different extinguisher liquids in question were studied for decomposition, using wet air, a quartz tube and a temperature of 800° Centigrade, which seemed best for the purpose.

Results of Experiments with Chemically-pure Carbon Tetrachloride.—The results of the experiments with pure carbon tetrachloride are summarized in Table III. Taking up the columns in order: Column 1 gives the number of determinations of each of the different gas constituents, of which the averages are reported in succeeding columns; results of at least three determinations are included. As stated under "Remarks," the differences were small, about two or three per cent. Column 3 gives the temperature of the heated tube; 600° and 800° Centigrade were used. Variations up to 15° from these temperatures occurred. Column 4 states the material of the heated tube. Iron was first used to obtain results comparable with those of the experiments with the channel irons in the gas chamber. Iron oxide on the surface was found to influence the reaction and a quartz tube was used later.

Columns 5 and 6 state respectively the amounts of carbon tetrachloride in the air passing through the hot tube, by weight, and by volume of the vapor as a perfect gas, at room temperature. Differences in concentrations varied over a range of about 8 per cent. Since the final figures are expressed in terms of percentage of these concentrations, the small differences should not influence the conclusions drawn.

TABLE III.

Results of Tests of Chemically Pure Carbon Tetrachloride. Rate of Flow of Air—Five Liters per Minute.

Number of tests averaged	Air condition	Temp. ° C.	Material of heated tube	Carbon tetrachloride (CCl_4) vapor in air		Decomposition products [a]								Undecomposed carbon tetrachloride (CCl_4) Calculated [c]		Chlorine in decomposition products compared to chlorine in original carbon tetrachloride (CCl_4) [d] Per cent.			
						Phosgene ($COCl_2$)		Chlorine (Cl_2)		Total chlorides [b] as hydrogen chloride. (HCl).		Hydrogen chloride (HCl). Calculated				Phosgene $COCl_2$	Chlorine (Cl_2)	Hydrogen chloride (HCl)	Undecomposed carbon tetrachloride (CCl_4)
				mg.p.l.	p.p.m.	mg.p.l.	p.p.m.	mg.p.l.	p.p.m.	mg.p.l.	p.p.m.	mg.p.l.	p.p.m.	mg.p.l.	p.p.m.				
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
3	Wet	600	Iron	92.6	14700	15.0	3700	5.0	1700	46.5	31000	30.2	20200	43.6	6920	12.6	5.9	34.4	47.1
4	Dry	600	Iron	91.8	14580	9.7	2400	28.0	9000	34.5	23000	−1.5 [e]	....	55.5	8810	8.3	33.1	−1.8 [e]	60.4
3	Wet	600	Quartz	86.0	13650	2.4	600	.7	210	3.6	2400	1.1	740	82.1	13000	2.2	.9	1.4	95.6
3	Dry	600	Quartz	90.2	14320	.0	0	1.1	400	2.0	1320	.8 [e]	....	88.1	14000	.0	1.3	.96 [e]	97.7
3	Wet	800	Quartz	84.8	13470	14.4	3550	16.2	5600	34.5	23000	7.2	4830	48.5	7700	13.2	20.7	8.9	57.2
3	Dry	800	Quartz	89.2	14170	12.8	3150	14.4	4970	24.4	16300	.1 [e]	....	63.5	10000	11.2	17.5	.1 [e]	71.2

REMARKS:

[a] Differences in triplicate analytical determinations of gases in the various experiments ranged up to a maximum of about 10 per cent. of their values.

[b] Chlorine is included in total chlorides, as it is absorbed and reduced to chlorides by the alcoholic sodium hydroxide solution used. Carbon tetrachloride did not react; ferric chloride was caught in cold tubes before reaching the absorbent. These are not included in total chlorides as determined.

[c] Possible compounds such as C_2Cl_4, C_2Cl_6, $CHCl_3$ and also $FeCl_3$ are calculated here as CCl_4 on a chlorine content basis.

[d] Since the phosgene generated can contain a maximum of only 50 per cent. of the chlorine content of the carbon tetrachloride, the percentage of carbon tetrachloride represented by the phosgene is twice that stated for chlorine content comparison. For the other gases, the percentages given for chlorine may be considered to represent also the percentage of the carbon tetrachloride decomposed to form the products.

Figures representing hydrogen chloride, less than one milligram per liter, or one per cent., have no value, because experimental errors exceed this. They are included only for use in comparisons.

Columns 7 to 16, inclusive, give the results of determinations of phosgene, chlorine, hydrogen chloride, total chlorides (as hydrogen chloride), and undecomposed carbon tetrachloride; each in terms of weight and gas volumes. The phosgene, chlorine and total chlorides were determined directly by analysis. Total chlorides includes the phosgene, hydrogen chloride and the chlorine, which was caught and reduced to chlorides by the alcoholic sodium hydroxide solution used, but does not include carbon tetrachloride, which did not react in the analysis; or any ferric chloride, which was precipitated from the gases by the cold tubes and glass wool put into them before the gases reached the absorbing solution.

Hydrogen chloride was calculated by subtracting from the weight of chlorine in the total chlorides the sum of the weight of chlorine in the phosgene and free chlorine, and converting the difference into hydrogen chloride. Undecomposed carbon tetrachloride was calculated by subtracting from the weight of chlorine in the original carbon tetrachloride the weight of chlorine in the total chlorides, and converting the difference into carbon tetrachloride. The figures for undecomposed carbon tetrachloride thus include any tetrachlorethylene (C_2Cl_4), hexachlorethane (C_2Cl_6), ferric chloride ($FeCl_3$), or chloroform ($CHCl_3$), computed on the basis of their chlorine content.

Columns 17 to 20, inclusive, give the percentages by weight of the chlorine apportioned among the products, phosgene, free chlorine, hydrogen chloride and undecomposed carbon tetrachloride. The figures for hydrogen chloride which are less than one per cent. have no value, because the experimental errors exceed them. They are included in the table only for use in making comparisons.

Phosgene generated from the carbon tetrachloride can contain a maximum of but 50 per cent. of the chlorine in the carbon tetrachloride. Hence, the molecular percentage of carbon tetrachloride which was converted into phosgene is twice that stated as a result of comparing their chlorine contents. For the other gases, the percentages given by comparing the chlorine in them with the chlorine in the original carbon tetrachloride, may be considered to represent the percentage of carbon tetrachloride decomposed to form them.

Discussion of the Results.—Table III shows that at 600°

TABLE IV.

Results of Tests with Commercial Fire Extinguisher Liquids and Heated Tube. Rate of Flow of Air—Five Liters per Minute; Air Condition—Saturated with Water Vapor at Room Temperature; Material of Tube—Quartz; Temperature at Middle of Tube—800° ± 10° Centigrade.

Fire extinguisher liquid	Number of tests averaged	Carbon tetrachloride (CCl_4) vapor in air		Decomposition products										Chlorine in decomposition products compared to chlorine in original carbon tetrachloride (CCl_4)			
				Phosgene ($COCl_2$)		Chlorine (Cl_2)		Total chlorides as hydrogen chloride (HCl)		Hydrogen chloride (HCl) calculated		Undecomposed carbon tetrachloride (CCl_4) calculated		Per cent.			
		mg.p.l.	p.p.m.	mg.p.l.	p.p.m.	mg.p.l.	p.p.m.	mg.p.l.	p.p.m.	mg.p.l.	p.p.m.	mg.p.l.	p.p.m.	Phosgene ($COCl_2$)	Chlorine (Cl_2)	Hydrogen chloride (HCl)	Undecomposed carbon tetrachloride (CCl_4)
Commercial carbon tetrachloride	3	91.4	14500	16.2	4000	15.8	5400	34.6	23200	6.4	4290	55.0	8730	13.8	18.7	7.4	60.1
No. 1	3	87.0	13800	15.0	3700	16.0	5500	32.2	21600	4.6	3090	53.1	8430	13.5	19.9	5.6	61.0*
No. 2	3	90.4	14350	14.4	3800	13.0	4400	32.8	22000	8.8	5900	55.8	8860	12.3	15.6	10.3	61.8†
No. 3	3	91.2	14480	15.0	3700	10.2	3500	31.9	21400	10.3	6910	59.6	9460	12.9	12.1	11.9	63.1‡

* Liquid contained chloroform.
† Liquid contained chloroform and keronene, or other heavy petroleum distillate.
‡ Liquid contained chloroform and turpentine.

Centigrade, carbon tetrachloride vapor in air decomposes much more readily in contact with iron or oxide of iron than in contact with a solid substance chemically inert to it, as quartz. Phosgene is generated in greater quantity when the atmosphere is moist than when dry; in fact, no phosgene was formed in dry air at 600° in contact with quartz, but in contact with oxide-covered iron, 8.3 per cent. of the chlorine in carbon tetrachloride changed to combination in phosgene.

More free chlorine was formed with dry air in the iron tube at 600° than in the quartz tube, and much more was formed in the iron tube with dry air than with wet.

On the whole, the presence of hot reactive substances, as either water vapor or oxide of iron, or possibly metallic iron, seems to promote the decomposition of carbon tetrachloride vapor, and the effect of the iron oxide is greater than that of the water vapor.

In the experiments with the quartz tube at 800° Centigrade, more of each of the decomposition products was formed than in the quartz at 600°, whether moisture was present or absent; and the greater production of each product occurred with the moisture present.

Equations (1) to (5) which have already been stated can account for most of the phenomena observed. In addition to these, the experiments with carbon tetrachloride vapor in dry air heated to 800° Centigrade gives rise to phosgene. This undoubtedly occurs according to this equation:

$$2CCl_4 + O_2 = 2\,COCl_2 + 2Cl_2 \qquad (6)$$

Of the conditions used in these experiments with the chemically-pure carbon tetrachloride, the quartz tube at 800° Centigrade and humid air, seemed to be most suitable for the study of the commercial liquids, so they were applied in the experiments following.

Results of Experiments with Commercial Fire-extinguisher Liquids.—Table IV gives the results of the experiments with the commercial liquids in the heated tube. Since the figures and the methods of obtaining them are like those reported for Table III, they need no special explanation. The figures show that at 800°, in presence of water vapor, commercial fire-extinguisher liquids may be decomposed to a large extent with formation of poisonous products. Phosgene was produced in nearly equal quantities

from all the liquids; 12.3 to 13.8 per cent. of the original chlorine was found in final combination as phosgene. Chlorine was produced as a result of decomposition of about 12 to 20 per cent. of the original carbon tetrachloride. The low figure, 12 per cent., was obtained with the liquid which had turpentine added to it. Turpentine, which is very active toward chlorine, thus seems to inhibit the formation of free chlorine, but it has little, if any, inhibiting effect on phosgene. Hydrogen chloride figures ranged from 5.6 to 11.9 per cent. As might be expected, the greatest amount was obtained with the liquid containing turpentine. About 60 to 63 per cent. of the liquids passed through the heat without decomposition.

Altogether the results of the experiments with the heated tubes entirely substantiate the results obtained with the actual fires and hot metal in the gas chamber, and confirm the conclusions that gases arising from the use of carbon tetrachloride liquids for extinguishing even small fires are poisonous and formed in sufficient quantity to poison the air of small unventilated spaces. Such extinguishers should not be used by persons unprotected from the fumes, who are unable to hold their breath long enough to escape from the dangerous atmosphere.

TOXICITY OF THE GASES.

Data on the toxicity to man and animals of carbon tetrachloride, chlorine, chloroform, hydrogen chloride and phosgene have been collected from reports made by various investigators and arranged for comparison in Table V.

Standards of measurement used by different investigators have not been uniform, so the different results are difficult to put into a homogeneous table. Some liberties have been taken in transposing and arranging some of the data. For this reason, reference to original sources, which are cited in all cases, should be made when exact statements are wanted. The table shows that the order of toxicity is this: (1) Phosgene, (2) chlorine, (3) hydrogen chloride, (4) carbon tetrachloride, and (5) chloroform.

METHODS OF ANALYSIS OF THE GASES.

The methods used and the necessary reagents and apparatus for determining chlorine, phosgene, hydrogen chloride and carbon tetrachloride in the air containing the decomposition products

are described very briefly below. Underlying principles were the same in analyzing the dilute gases from the chamber and the more concentrated ones from the heated tube. The volume of sample from the chamber was usually 4 or 5 litres at room temperature, and was taken by water aspirating and measurement of the water displaced. About one-tenth to one-fifth of this volume was used with the heated tube; measurement being made with the flow meter and length of time of passing the sample. The rate of passing the gases through absorbents was one litre per minute or less. Constituents were determined in the order stated.

Chlorine.—The measured gas sample was passed directly through 50 c.c. of a 5 per cent. solution of potassium iodide, contained in a tube with bubbler of the petticoat type. Liberated iodine was titrated with 3/100 normal sodium thiosulfate solution and starch indicator.

Phosgene.—The gas was passed through a train of reagents in this order:

(*a*) Silver nitrate on granular pumice contained in a tube as detailed in Fig. 4. This was for removing hydrogen chloride.

(*b*) Powdered antimony trisulfide, interspersed through glass wool contained in a similar tube, to remove chlorine.

(*c*) Fifty cubic centimetres of sodium hydroxide solution in 85 per cent. alcohol. This was for absorbing the phosgene, which hydrolyzed to produce sodium chloride. The chloride was determined by the Mohr method of titration with standard silver nitrate solution and potassium chromate indicator. A blank determination for chlorides in the caustic solution was subtracted from the results and phosgene then calculated.

A diagram of the apparatus used to take a sample of gas from the chamber for determining phosgene in the absence of chlorine is shown in Fig. 3.

The silver nitrate pumice was made by dissolving 100 grams of silver nitrate in 330 cubic centimetres of boiling water, adding to this approximately one litre of 8- to 14-mesh pumice, stirring thoroughly, cooling, draining excess fluid and drying in a water oven at 100° Centigrade.

Hydrogen Chloride.—Gas samples were aspirated directly through 50 cubic centimetres of the alcoholic caustic solution. All the chlorine in the form of free chlorine, phosgene and hydro-

TABLE V.

Toxicities of Air Containing Gases and Vapors from Fire Extinguishers.

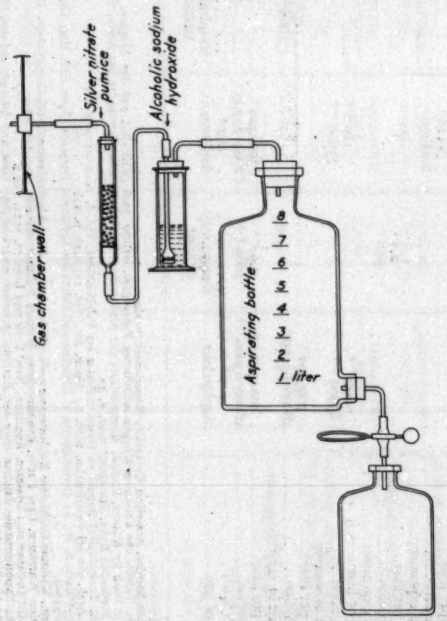
	Carbon tetrachloride	Chlorine	Chloroform	Hydrogen chloride	Phosgene
Least detectable odor:					
Milligrams per liter	4.5 [5]	0.010 [1]	3.3 [5]	.....	0.023 [1]
Parts per million	718 [5]	3.5 [1]	674 [5]	.....	5.6 [1]
Irritation:					
Eyes:					
Milligrams per liter	.....	.....	.....	.....	.016 [1]
Parts per million	.....	.....	.....	.....	4. [1]
Throat:					
Milligrams per liter	.....	0.44 [1]	.....	.....	.0126 [1]
Parts per million	.....	15.1 [1]	.....	.....	3.1 [1]
Coughing:					
Milligrams per liter	.....	.088 [1]	.....	.....	.019 [1]
Parts per million	.....	30.2 [1]	.....	.....	4.8 [1]
Slight symptoms after several hours:					
Milligrams per liter	10 [2]	.0029 [2]	1. [2]	.015 [2]	.004 [1]
Parts per million	1600 [2]	1. [2]	200 [2]	10 [2]	1. [1]
Maximum amount that can be inhaled for one hour without serious disturbances:					
Milligrams per liter	25–40 [2]	.012 [2]	25–30 [2]	0.075–0.150 [2]	.....
Parts per million	4000–6200 [2]	4. [2]	5100–6200 [2]	50–100 [2]	.....
Dangerous in thirty minutes to one hour:					
Milligrams per liter	150–200 [2]	0.12–0.17 [2]	70 [2]	2.2–3.0 [2]	.....
Parts per million	24000–32000 [2]	40–60 [2]	14000 [2]	1500–2000 [2]	.....
Noxiousness, impossible to breathe several minutes:					
Milligrams per liter	.....	0.015 [3]	.....	0.1–0.3 [1]	.02 [3]
Parts per million	.....	5 [3]	.....	66–200 [1]	5 [3]

Toxicity of lethal dose:					
Mice, 10 minute exposure:					
Milligrams per liter	.....	.....	>126 [1]	.....	0.4 [1]
Parts per million	.....	.....	>25900 [1]	.....	99 [1]
Dogs, 20 minute exposure:					
Milligrams per liter	.....	2.5 [1]	.....	.....	0.35 [1]
Parts per million	.....	860 [1]	.....	.....	86 [1]
Cats, 30 minute exposure:					
Milligram per liter	400 [6-8]	.....	120 [6-8]	.....	0.20 [1]
Parts per million	63000 [6-8]	.....	25000 [6-8]	.....	50 [1]
Man, 30 minute exposure:					
Milligrams per liter	300–400 [2]	.....	.....	1.5 [2-7]	0.10 [1]
Parts per million	48000–63000 [2]	.....	.....	1000 [2-7]	25 [1]
Kill most animals in very short time:					
Milligrams per liter	300–400 [2-4]	2.9 [2-4]	300–400 [2]	.....	.....
Parts per million	48000–63000 [2-4]	1000 [2-4]	62000–82000 [2]	.....	.....
Relative toxicity—$CCl_4 = 1$	1 [8]	.....	2.2 [8]	.....	.....
Physiological action of gas	Asphyxiant	Respiratory irritant	Asphyxiant	Respiratory irritant	Lachrymator-respiratory irritant

REFERENCES:
[1] Chemical Warfare Service, American University Experiment Station.
[2] Lehmann, K. B., Tabelle der Kleinsten Mengen schädlicher Fabrikgase, welche noch giftig sind und der Mengen, welche allenfalls ertragen werden; in book by Kobert, Rudolf, Kompendium der praktischen Toxikologie zum Gebrauche für Ärzte, Studierende und Medizinalbeamte, Ferdinand Enke, Stuttgart, 1912, p. 45.
[3] Kohn-Abrest, E., Toxicological Report on Gases, Annales des Falsifications, Vol. 8, 1915, pp. 215–239.
[4] Slovtzov, B. I., Arch. des Sci Veterinaries, 1916, 3: Chem. Ab., Vol. 12, 1918, p. 831.
[5] Allison, V. C., and Katz, S. H., An Investigation of Stenches and Odors for Industrial Purposes; Jour. Ind. Eng. Chem., Vol. 11, No. 4, April, 1919, pp. 336–8.
[6] Herrmann, Georg., Wirkung Gechlorter Kohlenwasserstoffe, Chloroform, Tetrachlorkohlenstoff, Trichlorathylene, Dichlorathylene; Inaugural Dissertation Wurzburg, Carl Fuchs, Buchdruckerei Mittere Fuhnspromenade, 1911, 50 pp.
[7] Thompson, W. G., Occupational Diseases, Appleton, New York and London, 1914, 724 p.
[8] Lehmann, K. B., Experimentelle Studien über den Einfluss technisch und wichtiger Gase und Dämpfe auf den Organismus (xvi–xxiii). Die Gechlorten Kohlenwasserstoffe der Fettreihe nebst Betrachtungen über die einphasische und zweiphasische Giftigkeit ätherischer Körper; Archieve für Hygiene, Vol. 74, 1911, pp. 1–60.

gen chloride is thus converted to sodium chloride. Carbon tetrachloride does not react. The total chloride produced was determined by the Mohr titration. Hydrogen chloride was computed from the results of this and previous determinations by the method described on page 555.

FIG. 3.

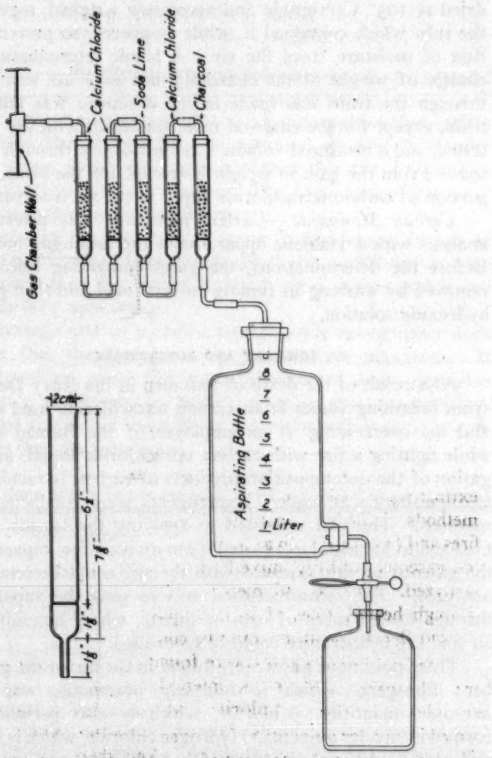


Apparatus for sampling phosgene in air of gas chamber when chlorine is absent.

Carbon Tetrachloride.—Carbon tetrachloride in the air of the chamber was determined by absorption in activated charcoal, and finding the increase in weight. The sample was passed through a train of reagents, illustrated in Fig. 4, which were placed in this order:

(*a*) Fused calcium chloride, 8- to 14-mesh granules, for drying the gases.

FIG. 4.



Apparatus for sampling carbon tetrachloride in air containing phosgene, chlorine and hydrogen chloride.

(*b*) Soda lime, 8- to 14-mesh granules, for removing phosgene, chlorine, hydrogen chloride and other acid gases from the fire.

(*c*) Calcium chloride, the same as before, to take up any moisture evolved by the soda lime.

(*d*) Charcoal, 8- to 14-mesh. The charcoal was previously dried at 105° Centigrade and accurately weighed, together with the tube which contained it, while stoppered, to prevent absorption of moisture from the air. A blank determination of the change of weight of the charcoal when pure air was aspirated through the train was made before a sample was taken. The train, except for the charcoal tube, was filled with the gas to be tested, and a measured volume was then drawn through the charcoal. From the gain in weight corrected for the blank, the proportion of carbon tetrachloride vapor in the air was computed.

Carbon Monoxide.—Carbon monoxide was determined by analysis with a Haldane apparatus in the usual gasometric way. Before the determinations, the gases containing chlorine were removed by washing in fuming sulfuric acid and then potassium hydroxide solution.

SUMMARY AND CONCLUSIONS.

As a result of the death of two men in the Navy Department from breathing fumes from carbon tetrachloride used on a fire, and the overcoming of an employee of the Bureau of Mines while fighting a fire with carbon tetrachloride liquid, an investigation of the decomposition products of carbon tetrachloride fire extinguishers was made. Experiments were conducted by two methods. The first consisted in applying the liquids to actual fires and to hot metal in a closed room of 1000-feet capacity where the gaseous products, mixed with the air, could be retained and analyzed. The second method was to pass the vapors in air through heated tubes of iron or quartz, where humidity of the air and the temperature could be controlled.

These poisonous gases were found in the air of the gas chamber: Phosgene, which is intensely poisonous, was formed in toxic quantities. Chlorine, which is also poisonous, was formed in smaller amounts. Hydrogen chloride, which is irritating and also poisonous, was formed. And there was considerable vapor of carbon tetrachloride, which is a dangerous anæsthetic. The experiments with the heated tubes substantiated the results found with actual fires, and indicated that these reactions can account for the poisonous gases:

$$CCl_4 + H_2O = COCl_2 + 2HCl$$
$$2CCl_4 + O_2 = 2COCl_2 + 2Cl_2$$
$$3CCl_4 + FeO_3 = 3COCl_2 + 2FeCl_3$$
$$2CCl_4 + \text{Heat} = C_2Cl_4 + 2Cl_2$$
$$CCl_4 + 2H_2O = CO_2 + 4HCl$$

One-half of the carbon tetrachloride liquid was decomposed to poisonous gases in some of the tube experiments.

As a result of the experiments, it is recommended that carbon tetrachloride fire extinguishers be not used on fires in closely-confined spaces where conditions are such that the user cannot escape without breathing the fumes. The Army type of gas mask offers good protection from the fumes.

It is not the intention of this paper to discourage the use of carbon tetrachloride extinguishers, which are excellent for stopping incipient fires, but rather to point out a danger which can occur with their application.

The average user of a carbon tetrachloride extinguisher does not know that the decomposition products are poisonous. It would, therefore, seem that manufacturers of such apparatus should put a plainly-lettered caution plate on each extinguisher, stating that the fumes from using the extinguisher must not be inhaled, as they are poisonous.

Comparison of the Wave-lengths of a Line in a Cyanogen Band in Sunlight and of the Same Line from a Terrestrial Source. A. PEROT. (*Comptes Rendus*, July 26, 1920.)—According to the generalized theory of relativity Einstein announces that the wave-length of a line in sunlight should be 1.000002 times as great as the wave-length of the same line in light of terrestrial origin. To subject this theoretical conclusion to the test of observation a series of measurements were made at the observatory at Meudon from May 8 to June 29, 1920. The ratio was found to be 1.00000222. The real difference in wave-length is .009 Angstrom units. Care was exercised to exclude the possibility that a high pressure in the sun might be the cause of the difference. When a correction due to the vertical motion of the absorbing layer had been applied the ratio became 1.0000016. The Einstein value lies between the corrected and the uncorrected numbers.

G. F. S.

Electrolytic Production of Hydrogen Peroxide.—F. W. SKIRROW and E. R. STEIN, Research Chemists, Shawinigan Laboratories, Quebec, presented a paper at the twenty-eighth meeting of the *American Electrochemical Society* (Cleveland, September 30–October 2, 1920), giving results of investigations as to the yield of persulphuric acid by electrolyzing sulphuric acid and sodium or potassium acid sulphate, and the subsequent conversion of this acid into hydrogen peroxide. Persulphuric acid was discovered by Berthelot, and its salts first prepared by Marshall (*Trans. Chem. Soc.*, 1891, vol. lix, 771). The production of the acid by electrical methods has received much attention. The authors give references to the literature on this phase of the subject. From persulphuric acid or persulphates, hydrogen peroxide may be prepared by distillation under reduced pressure. As ordinarily conducted the loss by decomposition is large, which Price and Friend found to be due to some small impurity. In order to prevent such loss Teichner applied a modification by which disintegrated or dissolved platinum, which is the main cause of the decomposition, is removed. Löwenstein devised a continuous distillation process which separates the peroxide rapidly from the impure solution. Peitzsch and Adolph took out a British patent for the purpose but of a different type. They use pure potassium persulphate, prepared electrolytically, eliminating any incidental impurities by crystallization. They obtain a 30 per cent. solution, with almost theoretical yield. They redistill the potassium persulphate under a much reduced pressure with sulphuric acid, by which the hydrogen peroxide is distilled as fast as formed. Recently, Levin has patented a method by which the peroxide is obtained from sodium persulphate derived by electrolysis of sodium acid sulphate. Sodium persulphate being very soluble, the impurities cannot be removed by simple crystallization, but are removed by filtering through porous earthenware, the electrolyte being periodically treated with hydrogen sulphide to remove platinum and lead.

The authors give in detail their own experiments and summarize their work as follows:

Platinum so far has been the only material suitable for the anode in these operations, with possible exception of manganese dioxide. The current efficiencies of persulphuric acid, sodium or potassium persulphate show no important difference, but the sodium salt can apparently be produced to a much higher concentration than the acid without sacrifice of efficiency. Distillation of the once recrystallized potassium salt, with dilute sulphuric acid, gives reasonably high yields of the peroxide. Distillation of persulphuric acid or its sodium salt must be preceded by a rigorous purification to remove catalytic impurities.

H. L.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

MEASUREMENTS OF THE THERMAL DILATATION OF GLASS AT HIGH TEMPERATURES.[1]

By C. G. Peters and C. H. Cragoe.

[ABSTRACT.]

THE methods and results of an investigation of the thermal expansion and the chemical composition of different kinds of optical glass, chemical glassware, and commercial tubing are presented in this paper. A ring of the glass, placed between two fused quartz plates, was heated in an electric furnace and its expansion measured by the Fizeau interference method. Observations were made in the temperature regions between 20° and 650° C. on thirty-two different kinds of glass. Their dimensional changes are represented by curves which show that the glass passes through a critical expansion region, in which the expansion rate increases by two to seven times. This critical region, which for any one glass does not exceed 40°, was found as low as 400° C. with one glass and as high as 575° C. with another. About 75° above the critical region the glass softens and contracts. A comparison of results shows that the heat absorption observed by Tool and Valasek occurs in the same temperature region as the critical change in the expansion.

From these determinations of the dimensional changes of glass, the following information is obtained: the thermal expansion above and below the critical temperature, the temperature for most careful and thorough annealing, the upper limit for rapid annealing, and the region where careful cooling is essential.

RECOMMENDED SPECIFICATIONS FOR GREEN PAINT—SEMI-PASTE AND READY MIXED.[2]

[ABSTRACT.]

THIS specification for green paint—semi-paste and ready-mixed, refers to a chrome green paint, either in semi-paste pigment ground in linseed oil, or ready-mixed. The specification

* Communicated by the Director.

[1] Scientific Paper No. 393.

[2] Circular No. 97.

covers the general conditions and the maxima and minima of useful, harmful, or neutral constituents and methods of sampling, and the details as to the laboratory examination and analysis. The detailed methods of preparing the reagents to be used are also given. The standard was prepared under the auspices of the Bureau of Standards and submitted to large numbers of representative paint manufacturers, and also recommended by the United States Interdepartmental Committee on Paint Specification Standardization.

AN EXAMINATION OF THE MUNSELL COLOR SYSTEM. I. SPECTRAL AND TOTAL REFLECTION AND THE MUNSELL SCALE OF VALUE.[3]

By Irwin G. Priest, K. S. Gibson and H. J. McNicholas.

[ABSTRACT.]

THIS paper gives the diffuse spectral reflection of twenty-four cards submitted by the Munsell Color Co., as standards of the Munsell Color System.[4] These cards included the nine grays and three each of the following hues: red, yellow, green, blue, and purple. The data were obtained by the following methods:

(*a*) Visual, Koenig-Martens Spectrophotometer for wave-lengths 700 to 436 millimicrons.

(*b*) Photo-electric, Gibson's apparatus,[5] for wave-lengths 600 to 390 millimicrons. In the overlapping regions, good agreement is shown between the two methods.

The "luminosities" or "total reflections" relative to magnesium carbonate in average sunlight are computed from the spectral-reflection data; and the *squares* of the Munsell "value" numbers are found to be proportional to these sunlight reflections.

The relation of the Munsell "value" scale to the natural or logarithmic scale is discussed.

Several recommendations for the improvement of the Munsell system are made with a view to the establishment of such a system on a more reliable and satisfactory foundation than exists at present.

---

[3] Technologic Paper No. 167.

[4] Atlas of the Munsell Color System, published by Wadsworth, Howland and Co., Boston. Address Munsell Color Co., 220 West 42d St., New York City. See also "A Color Notation," by A. H. Munsell, Boston, 1905, 1907, 1913, 1916.

[5] *Jour. Op. Soc. Am.*, Jan.-March, 1919. B. S. Sci. Papers, 349, Oct., 1919.

THE COLOR AND SPECTRAL COMPOSITION OF CERTAIN HIGH INTENSITY SEARCHLIGHT ARCS.*

By Irwin G. Priest, W. F. Meggars, K. S. Gibson, E. P. T. Tyndali and H. J. McNicholas.

[Abstract.]

In coöperation with the Searchlight Investigation Section, Corps of Engineers, U. S. A., quantitative measurements have been made on the color and relative spectral distribution of energy in the following arcs: Sperry searchlamp arc, Columbia and Speer carbons, 75 amperes, and ordinary arc, Electra carbons, 10 amperes. The range of wave-lengths included was from 430 to 720 millimicrons.

The Koenig-Martens spectrophotometer and the Arons chromoscope were used to obtain the data. Methods of measurement are described.

In addition, the spectra of these arcs at 10 amperes, obtained with a diffraction grating, are shown, and the results of spectroscopic analysis of the carbons are given.

The data obtained are given in the form of graphs and show that there is a great excess of radiation in the blue-violet, as compared to the rest of the visible spectrum, the color of the light being *approximately* equivalent to the light of the noonday sun at Washington, but with an excess intensity in the blue.

* Technologic Paper No. 168.

Water-power in Sweden. (*Chemical and Metallurgical Engineering*, September 22, 1920.)—The Swedish Government operation of water-power sites reports a gross income for 1919 amounting to 13,897,649 crowns and expenditures of 7,622,750 crowns. Nearly all the water-power plants now in operation show a profit to the government, and most of the expenditures are for additions and new construction work on power sites that have not yet been completed.

Critical Study of Methods for Detection of Methanol.—Methanol is the name recently proposed for methyl alcohol with a view to diminish the liability of it being used as an intoxicant. As the detection of it even in small quantities is important, much attention has been given to the subject and many methods suggested. A. O. GETTLER has submitted fifty-eight of these to critical examination and reports the results in a paper in *J. Biol. Chem.*, 1920, xlii, 311. The methods are conveniently divided into two groups; A, those in which the substance is converted into formaldehyde, and B, those in which it is tested for directly. Gettler finds that, all things considered, the A methods are more satisfactory. In the course of the examination over 250 liquors and 700 specimens of human viscera were tested. Improved methods are given for detection of the substance in liquors and in tissues. The procedure advised for its detection in liquors is as follows:

One hundred c.c. of the sample are neutralized with sodium carbonate, using phenolphthalein, in a 200 c.c. flask and slowly distilled until 50 c.c. of liquid is collected. This is divided into two portions, A, of 30 c.c., and B, of 20 c.c. A is tested as follows: 100 c.c. of 10 per cent. sulphuric acid are added in a 250 c.c. distilling flask, then 6 grm. of potassium dichromate, the mixture allowed to stand ten minutes, and then 30 c.c. distilled off slowly; that is, requiring about one hour. This distillate contains most of the acetaldehyde that may have been formed but very little formaldehyde. The distillation is then resumed a little speedier, until 60 c.c. are collected. The second distillate contains most of the formaldehyde and very little acetaldehyde and is used for the special tests. The special tests that have been found most satisfactory are five color reactions and two in which crystals are formed. The details of the procedures with these tests are given.

The methods in which the methanol is caused to unite directly with other substances are applicable only when rather large amounts are present. Twelve are described, most of which involve long and tedious manipulations. The most satisfactory of the series because it is simple, speedy and positive, is determination of the relation between the specific gravity and refractive index. This relation is so characteristic that it serves to detect methanol in common alcohol. As a color reaction the action of hydroxylamin on potassium hydroxide is good. After long boiling, cyanide is produced, ethyl alcohol, aldehyde, acetal and amyl alcohol not being affected. The cyanide can, of course, be easily detected.

The paper is from the Laboratory of the Pathological Departmen of Bellevue and Allied Hospitals, and is a most valuable contribution to the solution of a problem of great importance.

H. L.

NOTES FROM THE U. S. BUREAU OF CHEMISTRY.*

PICKERING SPRAYS.[1]

By F. C. Cook.

[ABSTRACT.]

AN investigation was undertaken to determine the efficacy of the so-called Pickering, or Pickering limewater, sprays, prepared by mixing saturated limewater with dilute solutions of copper sulphate, as compared with that of the ordinary Bordeaux sprays. The results of this investigation indicate that, on potatoes in Maine, the Pickering sprays are twice as effective as the Bordeaux mixture per unit of copper present. The stimulating and protective action exerted on potato plants was the same for each kind of spray. Pickering sprays adhered to potato leaves in practically the same degree as the standard Bordeaux, to apple leaves in a somewhat higher proportion, and to grape leaves in a lower proportion. It was shown that while Pickering sprays can not be used on tender foliage, they do not injure hardy foliage, as cranberry and potato leaves. A spray of the Pickering type, in which the limewater was replaced by barium water, gave satisfactory results.

Using these results as a basis, it is probable that the various agricultural experiment stations, as well as other interested agencies, will be able to devise formulas for sprays containing less copper sulphate than standard Bordeaux, which will be as effective as the more expensive material for certain crops.

STUDIES IN NUTRITION IV. THE NUTRITIVE VALUE OF PEANUT FLOUR AS A SUPPLEMENT TO WHEAT FLOUR.[2]

By Carl O. Johns and A. J. Finks.

[ABSTRACT.]

A DIET containing bread made from wheat flour (74 per cent. extraction) when fed to albino rats as the only source of protein and water-soluble vitamine, together with an adequate

* Communicated by the Chief of the Bureau.

[1] Bul. 866, issued August, 1920.

[2] Published in the *Jour. Biol. Chem.*, 42 (1920), 569.

inorganic salt mixture and butter fat produced only about one-third to two-thirds of normal growth.

Bread made from a mixture of 25 parts of peanut flour and 75 parts of wheat flour furnished adequate proteins and water-soluble vitamine for normal growth. A similar bread containing 15 parts of peanut flour and 85 parts of wheat flour contained proteins and sufficient water-soluble vitamine for growth at very nearly the normal rate.

Notes from American Chemical Society News Service, Bulletin 274, G. (From papers presented at the September, 1920, meeting of the Society.)—*Cheaper fuel* is indicated by the recent development of the colloidal fuel industry, a mixture of coal-dust and waste from petroleum having been found utilizable. By partially carbonizing lignite, a coke is obtained that may also be used as fuel. Comparative tests show that such half-coked material may be more economical than common coal for heating purposes. It is asserted by chemists that a large percentage of gasolin is wasted in motor vehicles by incomplete combustion.

Substitutes for cane sugar are still attracting attention. Bakers have become much interested in the new sweet-potato syrup, a process for the manufacture of which has just been developed by the Bureau of Chemistry of the U. S. Department of Agriculture. This syrup can be produced at small cost from potatoes that are of somewhat inferior quality, and, therefore, not readily marketable. Sweet potatoes of this grade are often alternated with cotton in the South in order to check the boll-weevil, and this will give a considerable supply of raw material. It is stated that the syrup is about as sweet as cane-sugar molasses, and, containing a very large amount of maltose, forms a rich brown crust on loaves and cakes in which it is used.

The substitution of glycerol for alcohol in the preparation of vanilla extract solves a problem which has been somewhat important in the present conditions.

The use of sawdust as a cattle food has been the subject of experiment in the Forest Products Laboratory in Wisconsin. By treating the waste of the buzz-saw with dilute sulphuric acid and neutralizing with lime, a soft, bran-like material is obtained, containing about 15 per cent. of water, upon which several cows fed for three months gained weight and gave more milk. The Department of Agriculture intends to experiment on a much larger scale.

Methods for the removal of ink from printed paper are under consideration by chemists interested in the cellulose industry.

H. L.

NOTES FROM THE U. S. BUREAU OF MINES.*

FUNDAMENTALS OF OIL-SHALE RETORTING.

By M. J. Gavin and Leslie H. Sharp.

THE U. S. BUREAU OF MINES, in coöperation with the State of Colorado, is conducting investigations at the University of Colorado to obtain fundamental data on the retorting of oil shale, particularly as regards the effects of certain variable factors in retorting on the quantity and quality of the products obtained from oil shales by destructive distillation. Experiments are being conducted in a specially designed retort, in which the principal factors that affect retorting conditions can be controlled or varied at will on representative oil shales. The physical and chemical properties of the shales, and the products yielded by them, are determined in a specially equipped testing laboratory.

The following data were obtained on oil shale from DeBeque, Colorado. The shale is of the massive variety, and yields oil of 0.905 specific gravity at the rate of 42.7 gallons per ton. The weight per cubic foot of the shale is: Run-of-mine, 53.775 pounds; +1 inch, 54.775; −1 inch, 56.015; −¼ inch, 58.200. Its specific gravity is 1.92 to 2.06. The specific heat (method of mixtures, Studentia calorimeter) of the raw shale is 0.265 (mean 20–90° C.) and of the spent shale, 0.223. The heat of combustion (in oxygen in Emerson calorimeter) of the raw shale is approximately 2460 calories per gram, and of the spent shale, 600. The thermal conductivity—raw shale—between 25 to 75° C. is −0.00382.

An analysis of the shale showed: Loss at 110° C. (moisture), 0.6 per cent.; loss on ignition, 40.0 per cent.; ash or residue, 59.4 per cent. The ash analyzed 44.70 per cent. SiO_2, and 25.60 per cent. Fe_3O and Al_2O_2, 17.65 per cent. CaO, 5.28 per cent. MgO, 6.77 per cent. undetermined matter.

The character of the work and the apparatus used are outlined in a paper entitled "Investigations of Fundamentals of Oil-shale Retorting." Results of the foregoing tests, with compara-

* Communicated by the Director.

tive tables of densities, specific heats, heats of combustion, and heat conductivities of various substances, are presented in a paper entitled "Some Physical and Chemical Data on Colorado Oil Shale."

MOTOR GASOLINE SURVEY.

By N. A. C. Smith.

IT has been known that the volatility of motor gasoline manufactured for sale during the winter months is less than that of gasoline made and sold in the winter. The Bureau of Mines, in its plans to make semi-annual surveys of the motor gasoline sold in the United States, has adopted the last half of January as the most satisfactory time to take samples of winter grades, and the last half of July for those of summer grade. The second semi-annual survey has been completed and the results show a greater decrease in volatility than can be accounted for as the normal change from winter to summer quality. The explanation seems to be that in order to supply the increased demand for motor fuel, refiners have cut deeper into the crude, thus increasing the amount of high-boiling material marketed as motor gasoline.

A paper containing tables showing the results of the distillation tests and analyses has been issued by the bureau.

RECOVERY OF GOLD FROM BLACK SANDS.

By John A. Davis.

THE BUREAU OF MINES, at its mining experiment station in Fairbanks, Alaska, is investigating methods of recovering gold from the "black sands" of placer clean-ups. A more efficient method than simple barrel amalgamation is needed for Alaskan mines, as the method oftentimes does not recover more than half the gold in the "black sand."

Tests on a magnetic black sand from a mine on Fairbanks Creek, more than 90 per cent. being magnetite and garnet, showed that 97 per cent. of the gold could be recovered by amalgamation in a barrel mill, with caustic soda added to aid amalgamation.

A black sand from St. Patrick Creek, which had been treated at the mine by amalgamation, still contained 11 cents gold per pound. Tests at the station showed that classifier concentration

and amalgamation would recover more than 80 per cent. of this gold.

The details of these tests are given in two reports entitled "Recovery of Gold from a Magnetic Black Sand," and "Recovery of Gold from Black Sand by Classifier Concentration."

MINOR NOTES.

Concentration of a Lead-zinc Tailing.—In flotation tests on low-grade complex ores of Colorado, being conducted by the Bureau of Mines, in coöperation with the State, at Golden, Colo., a locked test was made on a large sample of material from the Columbus dump at Eureka. It assayed 2.0 per cent. Pb, 3.6 per cent. Zn, 2.2 per cent. Fe, 0.28 per cent. Cu, a trace of Au, and about 1 oz. Au per ton. There was obtained a lead concentrate and a zinc concentrate. The former assayed 31 per cent. Pb, 20 per cent. Zn, 13 per cent. Fe, and 3 per cent. Cu, the recovery of lead being 75 per cent. The zinc concentrate contained 2.6 per cent. Pb, 57 per cent. Zn, 3 per cent. Fe, and 2 per cent. Cu, the recovery of zinc was low because of the proportion going with the lead. To crush the mill feed through 30-mesh is ample; the material between 30-mesh and 100-mesh fineness is then tabled to make a mixed sulphide concentrate and a low-grade tailing. By this means 48 per cent. of the mill feed is discarded. The mixed sulphide is then ground to pass 100-mesh and floated with the natural 100-mesh mill feed. This procedure gives low tailings and large mill capacity.

Hydrogen in the Coke Furnace.—In the study of conditions governing the sulphur equilibrium between gas and coke in retorting furnaces, experiments with atmospheres high in hydrogen showed that with coke containing 1.4 per cent. sulphur, hydrogen takes up 1.2 pounds per 1000 cubic feet of gas, the temperature being 900° C. but the volume of gas being computed at ordinary temperature. As the sulphur content of the coke decreases, the sulphur saturation point of the hydrogen becomes less. Observations on pure pyrite and hydrogen indicate that pyrite when heated in the presence of hydrogen is almost completely decomposed at 500° C. into H_2S and FeS, whereas without hydrogen little decomposition takes place at this temperature. At higher temperatures the hydrogen does not unite with the sulphur of the FeS formed.

The Spectrum of Hydrogen Positive Rays. G. P. THOMSON. (*Phil. Mag.*, August, 1920.)—There are two quite different spectra obtainable from hydrogen. In one but few lines are easily obtainable and the wave-lengths of these are related to one another by derivation from a common formula—the Balmer series. The other spectrum has more lines and these have not been reduced to any law. The origin of the two spectra has been in doubt. Sir J. J. Thomson's method of analyzing positive rays makes possible the separation of such rays as are due to atoms from those due to molecules and the identification of each kind.

The problem attacked by the investigator was to get positive rays consisting chiefly of hydrogen atoms and to photograph their spectrum and, again to obtain rays of molecules and examine their spectrum. He found that size and other geometrical relations of the apparatus affected the relative proportions of atoms and molecules. He succeeded in getting rays with few or no molecules. Such rays showed the Balmer series lines alone. He could not get rays of molecules exclusively. The best result attained was a marked preponderance of molecules. Then the spectrum was of the second kind with, of course, lines of the first plainly visible, agreeing with the known presence of atoms in the stream of rays. He concludes that the Balmer series spectrum is emitted by atoms and the second spectrum by molecules.

G. F. S.

An Economical Method of Utilizing the Force of the Tides. G. BIGOURDAN. (*Comptes Rendus*, July 26, 1920.)—As a result of the wanton destruction of the French coal mines by Germany the scientists of France are seeking to utilize whatever sources of energy are available in their country. In the Pyrenees and in the Alps the "white coal" of the waterfalls is largely used. The "green coal" of the tidal energy remains to be exploited, and for the industrial development of the country it is especially desirable to do this because its chief seat is in the northwest far away from the water-power of the mountains. The author renews a suggestion made by him in 1910. Let a diving bell be fixed in the water. As the tide rises the water would ascend within it and compress the enclosed air. As the tides run out there would be an aspiration of air into the bell. Both the compressed and the rarefied air could be used to transmit power. The bell would be a sort of pump in which the piston, moved by the sun and moon, makes rather more than two strokes per day. The claim is made that such an arrangement avoids the drawbacks caused by the intermittent character and the inequality of the tides and that its manipulation would be chiefly a matter of cocks and sluices requiring the services of but few attendants.

G. F. S.

THE FRANKLIN INSTITUTE.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, September 1, 1920.)

HALL OF THE INSTITUTE,
PHILADELPHIA, September 1, 1920.

MR. CHARLES PENROSE *in the Chair.*

The following reports were presented for first reading:

No. 2751: Radojet Air Pump.

No. 2754: Dr. W. L. R. Emmet's Work on the Electrical Propulsion of Ships.

R. B. OWENS,
Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(Stated Meeting, Board of Managers, September 8, 1920.)

RESIDENT.

DR. E. H. GRAFTON, Quaker City Rubber Company, Wissinoming, Philadelphia, Pennsylvania.

MR. PERCY S. LYON, care of H. S. B. W.-Cochrane Corporation, 17th and Allegheny Avenue, Philadelphia, Pennsylvania.

MR. FREDERIC BOWERS LYSLE, Room 900, City Hall, Philadelphia, Pennsylvania.

MR. HOMER REED, JR., 700 Franklin Bank Building, Philadelphia, Pennsylvania.

NON-RESIDENT.

MR. E. GORGAS BASHORE, Rice & Bashore, Highland Building, Pittsburgh, Pennsylvania.

MR. F. E. BRIMMER, Hydrocarbon Chemical Company, Lancaster, Pennsylvania.

MR. JOSEPH V. MEIGS, 53 Marietta Avenue, East Braintree, Massachusetts.

CHANGES OF ADDRESS.

MR. EDWIN S. BARNETT, 7011 Cresheim Road, Mt. Airy, Philadelphia, Pennsylvania.

MR. G. EDWARD BARNHART, 191 Marion Avenue, Pasadena, California.

MR. EDWARD BARTOW, Chemistry Department, State University of Iowa, Iowa City, Iowa.

MR. CHARLES E. BONINE, Franklin Trust Building, 20 South 15th Street, Philadelphia, Pennsylvania.

MR. WILLIAM C. FARNUM, 59 Mt. Vernon Street, Fitchburg, Massachusetts.

MR. ALEX. P. GEST, 5979 Drexel Road, Philadelphia, Pennsylvania.
MR. WALTER F. HAGAR, JR., Keystone Screw Company, Yardley, Pennsylvania.
MISS EMILY E. HOWSON, Agnes Scott College, Decatur, Georgia.
MR. J. C. JOHNSON, General Superintendent Transportation, Pennsylvania Railroad Company, Broad Street Station, Philadelphia, Pennsylvania.
MR. JONATHAN R. JONES, 1800 Widener Building Philadelphia, Pennsylvania.
MR. C. T. MACK, Doherty Men's Club, 1329 K Street, N. W., Washington, District of Columbia.
DR. LESLIE DENIS SMITH, Color Investigation Laboratory, Bureau of Chemistry, U. S. Department of Agriculture, Washington, District of Columbia.
MR. CLINTON F. SNYDER, Minersville, Pennsylvania.
MR. ORIN C. STOUT, 1369 East Main Street, Columbus, Ohio.

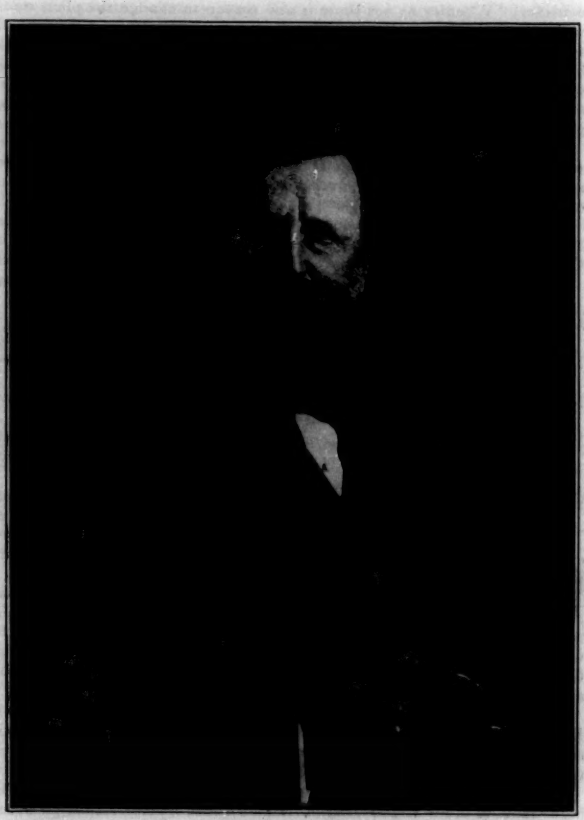
NECROLOGY.

Isham Randolph: On August 2, 1920, the engineering profession sustained an irreparable loss in the death, after a sudden and brief illness, of Dr. Isham Randolph.

Isham Randolph was born in New Market, Clark County, Virginia, in 1848. He acquired his education, especially in the engineering field, through assiduous study outside of duty hours, and through actual experience. At the age of twenty he entered the engineering profession as an axman on the Winchester and Strausburg Railroad. For the following twelve years he occupied various positions on railroad construction and operation, successively as leveler, transitman, resident engineer, assistant engineer, and roadmaster in the employ of several railroads until, in 1880, when he came to Chicago to fill the position of Chief Engineer of the Chicago and Western Indiana Belt Railway. From 1885 to 1893 he was engaged in general engineering practice with an office in Chicago. During this period he was employed by the Illinois Central Railroad as Chief Engineer to locate and build the Chicago, Madison and Northern Railroad, and the Freeport and Dodgeville Line. He also acted as Consulting Engineer for the Union Stock Yards and Transit Company, and the Baltimore and Ohio Railroad Company.

On June 7, 1893, he was appointed Chief Engineer of the Chicago Sanitary and Ship Canal (the Chicago Drainage Canal). He directed this large enterprise for fourteen years, from almost its very beginning to its final completion. This artificial channel is second only to the Panama Canal in size, and its cost was around sixty millions of dollars. Its construction was marked by excellent progress and efficiency throughout until its final successful completion. This great work contributed largely to Isham Randolph's fame as engineer. It was recognized by the Paris Exposition of 1900 by awarding him a gold medal.

While engaged on this work he was appointed by President Roosevelt to act as a member of the Board of Consulting Engineers for the Panama Canal, and was one of the five members of the Board whose minority report was accepted by the President and Secretary of War and adopted by Congress, and in accordance with which the Canal has been



ISHAM RANDOLPH
1848-1920

completed. In 1908 he was one of the six engineers invited by President Roosevelt to accompany Mr. Taft, then President-elect, to Panama to consider: "Whether or not there is any reason to change the plans upon which we are now working." This Board in its report of February 16, 1909, upheld unanimously the plans for a lock canal as now built. It will be remembered that the majority of the original commission consisting of some of the most eminent American and European engineers, recommended a sea-level canal. Subsequent experience with the Culebra Cut proved the wisdom of the minority report.

The Obelisk Dam above the Horseshoe Falls of the Niagara River was designed and built by him. It was built on end on the river bank, like an obelisk, and then tilted over into the rapids. The operation was entirely successful.

He served on numerous commissions either as chairman or member. The following are only a few of the positions he occupied:

Chairman of the Internal Improvement Commission of Illinois, which made plans for a canal from Lockport, Ill., to Utica, Ill., including hydro-electric power development of 140,000 horsepower.

Member of the Illinois State Conservation Commission, examining and reporting on the conservation of the national resources of the State.

Member of the Rivers and Lakes Commission of Illinois, which has jurisdiction over the rivers and lakes of the State.

Member of the Chicago Harbor Commission, which made a report and prepared plans for a lake-front harbor in Chicago.

Member of the Water Supply Commission of the City of Toronto, which made complete plans for a new water supply and water works system for that city.

Chairman of the Florida Everglades Engineering Commission, reporting to the State of Florida on the drainage of Everglades swamp lands. In this instance he was under a personal contract with the State and employed the other members of the Commission. The completed report was submitted to the Governor and made public.

He made a study and prepared a report and plans for a commercial harbor for the City of Milwaukee, Wis. He was Consulting Engineer on track elevation for the cities of Baltimore, Md., and Toronto, Canada. He was Consulting Engineer for the Little River Drainage District of Cape Girardeau, Mo., advising on the plans for the drainage of some 500,000 acres of land.

Doctor Randolph was a member of the American Society of Civil Engineers, Past President and member of the Western Society of Engineers, Member of the American Association of Engineers, The Franklin Institute, the Illinois Society of Engineers and the British Royal Society of Arts.

The above list, although far from complete, is sufficient to show the high standing in the engineering profession which Doctor Randolph occupied, and the unlimited confidence of the public he enjoyed, for the name of Isham Randolph attached to any enterprise was a guarantee of honesty, integrity and technical efficiency.

On June 15, 1910, the University of Illinois conferred upon him the

degree of "Doctor of Engineering," the Washington and Lee University, of Virginia, conferred upon him the degree of "Doctor of Commercial Science," and in February, 1913, The Franklin Institute of Philadelphia, Pennsylvania, conferred upon him the "Elliott Cresson Medal," the highest award in the gift of the Institute, "In recognition of Distinguished Achievements in the Field of Civil Engineering."

During the great war, Isham Randolph proved himself to be an ardent patriot. He was President of the Citizens' Unit of the 108th Engineers, and largely instrumental in organizing it. He made, entirely without compensation, confidential inspection of several military camps and reported thereon to the Secretary of War.

Coupled with this remarkable record of professional and social activities were Isham Randolph's personal qualities, which made it a great privilege to know him and which made him beloved of all who came in close touch with him. A heart most kind and generous, a mind most cultured and subtle, a soul most noble.

RALPH MODJESKI.

Benjamin Smith Lyman, geologist, mining engineer and inventor, was born at Northampton, Massachusetts, December 11, 1835, and died at Cheltenham, Pennsylvania, August 30, 1920. His educational training was begun in his native city, and in 1855 he was graduated from Harvard University, receiving the degree of Bachelor of Arts. He spent three years at the School of Mines, in Paris, and two years at the Royal Academy of Mines, in Freiberg, Saxony. His professional career began as Assistant State Geologist of Iowa, in 1858. After devoting several years to private geological work he was appointed mining engineer under the Public Works Department of the Government of India, giving special attention to the surveying of oil fields. From 1873 to 1879 he was Chief Geologist and Mining Engineer to the Government of Japan. In 1887 he was appointed one of the Assistant Geologists of the Second Pennsylvania Geological Survey and served in this capacity for nine years. He made geological excursions through the United States, British America, India, China, Japan, the Philippines and many parts of Europe. He was the author of over 150 papers on Geology, Geological Surveying and other subjects. Mr. Lyman was a member of over twenty-five of the leading scientific and technical societies of the world. He became a member of The Franklin Institute in 1890, and for a number of years was very active on its Library Committee, serving two years as its Chairman.

LIBRARY NOTES.

PURCHASES.

CLERC, L. P.—Les Productions Photomecaniques Polychromes. 1919.

GREY, C. G.—All the World's Aircraft. 1919.

HEAVISIDE, OLIVER.—Electromagnetic Theory. Vols. i–iii. 1893–1899.

HUYGENS, C.—Treatise on Light. 1912.

RÜDISÜLE, A.—Nachweis, Bestimmung und Trennung der chemischen Elemente. Vol. i to v. 1913–1918.

THOMPSON, J. S. AND H. G.—Silvanus Phillips Thompson: His Life and Works. 1920.
TOPHAM, JOHN.—French Technical Words and Phrases. 1919.
TROTTER, A. P.—Illumination. 1911.
WALKER, JAMES.—Introduction to Physical Chemistry. 1919.
Year Book of Wireless Telegraphy and Telephony. 1920.

GIFTS.

Acme Machinery Company, Catalogue No. 20. Cleveland, Ohio, 1920. (From the Company.)
Adams Company, Catalogue No. 58, Farwell Milling Machine. Dubuque, Iowa, 1920. (From the Company.)
Adams-Bagnall Electric Company, Catalogue No. 175, Abolites. Cleveland, Ohio, 1919. (From the Company.)
American Kron Scale Company, The Kron Scale. New York City, New York, 1920. (From the Company.)
Atlantic Refining Company, The Story of Gasoline. Philadelphia, Pennsylvania, 1920. (From the Company.)
Audubon Wire Cloth Company, Catalogue No. 31. Audubon, New Jersey, 1920. (From the Company.)
Baldwin Locomotive Works, Pamphlet No. F-2. Philadelphia, Pennsylvania, 1920. (From the Company.)
Barnstead Still and Sterilizer Company, Barnstead Patent Water Purifier and Still. Chicago, Illinois, 1920. (From the Company.)
Benjamin Electric Manufacturing Company, Catalogue No. 22. Chicago, Illinois, 1920. (From the Company.)
Black and Decker Manufacturing Company, Special Machinery. Baltimore, Maryland, 1920. (From the Company.)
Blanchard Machine Company, The Blanchard Grinder, Data Book. Cambridge, Massachusetts, 1920. (From the Company.)
Breeze Manufacturing Company, Flexible Metal, Hose Tubing and Accessories. Newark, New Jersey, 1920. (From the Company.)
British Columbia Minister of Mines, Annual Report for 1919. Victoria, British Columbia, 1920. (From the Minister of Mines.)
British Thomson-Houston Company, Ltd., Mazdalux Metal Reflectors. London, England, 1920. (From the Company.)
Bucyrus Company, Bulletin SP 501, Bucyrus Spreader Plow. South Milwaukee, Wisconsin, 1920. (From the Company.)
Buffalo Forge Company, Catalogue No. 421, Niagara Conoidal Fans; Catalogue No. 700, Heating, Ventilating and Humidifying; Catalogue 721, Dyehouse and Bleachery Ventilation. Buffalo, New York, 1920. (From the Company.)
Butterfield and Company, Catalogue No. 18, Taps and Dies. Derby Line, Vermont, 1920. (From the Company.)
Calcutta Meteorological Department, Monthly Rainfall Reports for 1916, 1917 and 1918. Calcutta, India. (From the Meteorological Department.)
Canadian Krantz Electric and Manufacturing Company, Catalogue 12-A. Toronto, Ontario, Canada, 1920. (From the Company.)

Canton Foundry and Machine Company, Portable Floor Cranes and Hoists. Canton, Ohio, 1920. (From the Company.)

Chapman Valve Manufacturing Company, Catalogue No. 38. Indian Orchard, Massachusetts, 1920. (From the Company.)

Chicago Belting Company, Catalogue on Belting. Chicago, Illinois, 1920. (From the Company.)

Clark Equipment Company, Putting Mettle into Metal. Buchanan, Michigan, 1920. (From the Company.)

Columbia University, Catalogue, 1919-1920. New York City, New York, 1920. (From the University.)

Columbus Conveyor Company, General Catalogue No. 5. Columbus Ohio, 1920. (From the Company.)

Combustion Economy Corporation, Powdered Coal and Malleable Iron Melting. Chicago, Illinois, 1920. (From the Corporation.)

Consolidated Pneumatic Tool Company, Ltd., Pneumatic Tool Catalogue No. 41. London, England, 1920. (From the Company.)

Cutler-Hammer Manufacturing Company, Machine Tool Control No. 845. New York City, New York, 1920. (From the Company.)

Detroit Graphite Company, Lighting Industrial Interiors. Detroit, Michigan, 1920. (From the Company.)

Dixon, Joseph, Crucible Company, Dixon's Silica-Graphite Paint and Colors and Specifications. Jersey City, New Jersey, 1920. (From the Company.)

Drake Process, Inc., Liquid, Semi-Liquid and Dry Containers and Other Articles from Pulp. Cleveland, Ohio, 1920. (From the Company.)

Dwight Manufacturing Company, Catalogue No. 10, Flue Gas Analyzers. Chicago, Illinois, 1920. (From the Company.)

Electric Furnace Company, Booklets 7-B and 8-B, Baily Electric Furnaces. Alliance, Ohio, 1920. (From the Company.)

Electric Service Supplies Company, Bulletin No. 166. Philadelphia, Pennsylvania, 1920. (From the Company.)

Engineer Company, The Development of an Idea. New York City, New York, 1920. (From the Company.)

Erie Commissioners of Water Works, Forty-second Annual Report, 1908. Erie, Pennsylvania. (From the Commissioners.)

Evans, John R. and Company, Shoe and Leather Reporter for 1920. Philadelphia, Pennsylvania, 1920. (From the Company.)

Fafnir Bearing Company, Booklet No. 20. New Britain, Connecticut, 1920. (From the Company.)

Florida East Coast Railway Company, Annual Report for 1919. New York City, New York, 1920. (From the Company.)

Foster Instrument Company, Radiation Pyrometry, Book No. 23. Letchworth, England, 1920. (From the Company.)

Foster Machine Company, Catalogue on Foster Machinery. Elkhart, Indiana, 1920. (From the Company.)

Fowler, John, and Company, Road Rollers, Cultivating Machinery, and Traction Engines. Leeds, England, 1920. (From the Company.)

Freeman Pattern Supply and Manufacturing Company, Catalogue No. 6. Toledo, Ohio. (From the Company.)

Gaertner, Wm., and Company, Optical Instruments, Catalogue L. Chicago, Illinois, 1920. (From the Company.)

Gas Combustion Company, The Bradshaw Burner. Pittsburgh, Pennsylvania, 1920. (From the Company.)

Gifford-Wood Company, Catalogue No. 19, Coal Handling Machinery. Hudson, New York, 1920. (From the Company.)

Goddard and Goddard Company, Catalogue B, Special and Standard Milling Cutters. Detroit, Michigan, 1920. (From the Company.)

Griscom-Russell Company, Bulletins No. 1111, Stratton Air Separator, and No. 1130, Bundy Oil Separator. New York City, New York, 1920. (From the Company.)

Gurney Ball Bearing Company, Ball Bearing Engineering Bulletin No. G-2. Jamestown, New York, 1920. (From the Company.)

Hall Planetary Thread Milling Machine Company, Bulletin on Hall "Planetary" Thread Milling Machines. Philadelphia, Pennsylvania, 1920. (From the Company.)

Hess Steel Corporation, Hess Electric Forging Steel. Baltimore, Maryland, 1920. (From the Corporation.)

Historical Sketch of American Leather Making. Salem, Massachusetts, 1916. (From the Philadelphia Book Company.)

Hi-Voltage Equipment Company, Bulletin No. 1, July, 1920. Cleveland, Ohio. (From the Company.)

Houghton, E. F. and Co., Catalogue No. 6, August, 1920. Philadelphia, Pennsylvania. (From the Company.)

Howard Iron Works, Pioneer Builders of Bolt, Nut and Special Machinery. Buffalo, New York, 1920. (From the Works.)

India Geological Survey, Memoir No. 1, Vol. vii. Calcutta, India, 1920. (From the Survey.)

Ingersoll Milling Machine Company, Bulletins Nos. 37, 38 and 39. Rockford, Illinois, 1920. (From the Company.)

Ingersoll-Rand Company, Bulletin No. 3330, Air Compressors. New York City, New York, 1920. (From the Company.)

Institution of Civil Engineers, Minutes of Proceedings, Vol. ccv. London, England, 1920. (From the Institution.)

Jeffrey Manufacturing Company, Catalogue No. 175. Columbus, Ohio, 1920. (From the Company.)

Lagonda Manufacturing Company, Lagonda Boiler Tube Cutters and Arch Tube Cleaners. Springfield, Ohio, 1920. (From the Company.)

Lake Superior Loader Company, Shuvloder. Duluth, Minnesota, 1920. (From the Company.)

Langelier Manufacturing Company, Drilling Machines and Drilling and Tapping Machines. Arlington, Cranston, Rhode Island, 1920. (From the Company.)

Leland Stanford University, Scale Insects of the Santa Cruz Peninsula and The Modern English Verb-Adverb Combination. Stanford University, California, 1920. (From the University.)

Link-Belt Company, Link-Belt Traveling Water Screens, Book No. 352. Chicago, Illinois, 1920. (From the Company.)

Louisiana State University, Catalogue, 1920. Baton Rouge, Louisiana. (From the University.)

Lovejoy Tool Works, Catalogue No. 10, Tools and Machinery. Chicago, Illinois, 1920. (From the Company.)

Luitwieler Pumping Engine Company, Automatic Electric and Hydro-Pneumatic Pressure Water Systems. Rochester, New York, 1920. (From the Company.)

MacGovern and Company, Power Machinery. New York City, New York, 1920. (From the Company.)

McNab Company, McNab Encyclopædia of Marine Appliances. Bridgeport, Connecticut, 1920. (From the Company.)

Mason Regulator Company, General Catalogue No. 60. Boston, Massachusetts, 1920. (From the Company.)

Michigan Department of Health, Forty-seventh Annual Report. Lansing, Michigan, 1920. (From the Commissioner of Health.)

Mine and Smelter Supply Company, Bulletin No. 60, Mechanical Rubber Goods. New York City, New York, 1920. (From the Company.)

National Acme Company, Dies and Taps. Cleveland, Ohio, 1920. (From the Company.)

Nicholson, W. H., and Company, The Wyoming Steam Trap. Wilkes-Barre, Pennsylvania, 1920. (From the Company.)

Niles-Bement-Pond Company, Circular No. 247, Right Line Radial Drills. New York City, New York, 1920. (From the Company.)

Norton Company, Grinding Wheels and Machinery. Worcester, Massachusetts, 1920. (From the Company.)

Ohio Electric and Controller Company, Bulletin No. 104, Lifting Magnet. Cleveland, Ohio, 1920. (From the Company.)

Ontario Bureau of Mines, Twenty-ninth Annual Report for 1920. Toronto, Canada, 1920. (From the Bureau.)

Ontario Hydro-Electric Power Commission, Twelfth Annual Report for 1919, and Hydro-Electric Power in the Niagara District and Province of Ontario. Ontario, Canada, 1920. (From the Commission.)

Osgood Company, Osgood Machinery of Various Types. Marion, Ohio, 1920. (From the Company.)

Pennsylvania Department of Labor and Industry, Third Industrial Directory. Harrisburg, Pennsylvania, 1920. (From the Department.)

Pennsylvania Electric Association, Twelfth Annual Convention, Proceedings, 1919. Bedford Springs, Pennsylvania. (From the Philadelphia Electric Company.)

Pennsylvania Forge Company, Catalogue No. 3. Bridesburg, Philadelphia, Pennsylvania, 1920. (From the Company.)

Pennsylvania Tank Car Company, Catalogue of Pennsylvania Tank Cars. Sharon, Pennsylvania, no date. (From the Company.)

Pettinos, George F., Graphite Products. Philadelphia, Pennsylvania, 1920. (From Mr. George F. Pettinos.)

Philadelphia Maritime Exchange, Forty-fifth Annual Report of the Board of Directors. Philadelphia, Pennsylvania, 1920. (From the Exchange.)

Philadelphia Rapid Transit Company, Result of Negotiations, re: Proposed Car Trust. Philadelphia, Pennsylvania, 1920. (From the Company.)

Pittsburgh, Cincinnati, Chicago and St. Louis Railroad Company, Third Annual Report. Pittsburgh, Pennsylvania, 1920. (From the Company.)

Pontelec Welding Patents, Ltd., Catalogue. Birmingham, England, 1920. (From the Company.)

Portable Machinery Company, Portable Conveyors. Passaic, New Jersey, 1920. (From the Company.)

Pyrolectric Instrument Company, Bulletin No. 13. Trenton, New Jersey, 1920. (From the Company.)

Ross-Tacony Crucible Company, Catalogue, no date. Tacony, Philadelphia, Pennsylvania. (From the Company.)

Ryerson, Joseph T., and Son, Ryerson Machinery. Chicago ,Illinois, 1920. (From the Company.)

Shanghai Municipal Council, Report for the Year 1919 and Budget for the Year 1920. Shanghai, China, 1920. (From the Council.)

Siemens Brothers and Company, Ltd., Loud-Speaking Marine Telephones. London, England, 1920. (From the Company.)

Smith & Serrell, Bulletin No. 102, Pintite Rigid Couplings. Newark, New Jersey, 1918. (From the Company.)

Societe des Ingenieurs Civils de France, Annexe Annuaires de 1920 a 1930. Paris, France, 1920. (From the Society.)

Society of Naval Architects and Marine Engineers, Transactions, 1919. Washington, District of Columbia, 1920. (From the Society.)

South Bend Lathe Works, How to Make an Eight-inch Bench, How to Build an Eight-inch Grinder, Machine Shop Equipment, South Bend Lathes, How to Run a Lathe. South Bend, Indiana, 1920. (From the Works.)

Sprague Electric Works, Bulletin, Sprague Flexible Steel Armored Hose. New York City, New York, 1920. (From the Works.)

St. Louis Water Commissioners, Annual Report for Year Ending April, 1920. St. Louis, Missouri, 1920. (From the Commissioners.)

Strong, Carlisle and Hammond Company, Catalogue No. 24. Cleveland, Ohio, 1920. (From the Company.)

Textile World Journal, Buyer's Guide for Textile Mills, 1920. New York City, New York. (From the Journal.)

Union Switch and Signal Company, Bulletin No. 93. Swissvale, Pennsylvania, 1920. (From the Company.)

United Engineering and Foundry Company, United Heavy-Duty Tod Engines. Pittsburgh, Pennsylvania, 1920. (From the Company.)

University of Iowa, Catalogues for 1915-1916 and 1916-1917. Iowa City, Iowa. (From the University.)

University of Maryland, Catalogue, 1920-1921. College Park, Maryland, 1920. (From the University.)

University of Nebraska, Annual Catalogues, 1920-1921, of College of Engineering, Law, Fine Arts, Arts and Sciences, Pharmacy and Graduate College. Lincoln, Nebraska, 1920. (From the University.)

University of North Dakota, General Catalogue, 1919-1920. University Station, North Dakota, 1920. (From the University.)

University of Pennsylvania, Catalogue, 1919-1920. Philadelphia, Pennsylvania, 1920. (From the University.)

University of Pittsburgh, General Catalogue, 1919-1920. Pittsburgh, Pennsylvania, 1920. (From the University.)

University of South Dakota, Catalogue, 1919-1920. Vermillion, South Dakota, 1920. (From the University.)

University of Utah, Catalogue, 1920-1921. Salt Lake City, Utah, 1920. (From the University.)

University of Wyoming, Catalogue, 1920. Laramie, Wyoming. (From the University.)

U. S. Department of Commerce, Statistical Abstract, 1919. Washington, District of Columbia, 1920. (From the Department.)

Vacuum Oil Company, Bearings and Their Lubrication. New York City, New York, 1920. (From the Company.)

Valuation of the Properties of Public Utility Corporations. Philadelphia, Pennsylvania, 1913. (From Charles Gobrect-Darrach, C.E.)

Vickers Leeds, B. R. Engineering Company, Ltd., Propeller Tail-Shafts of Ships. London, England, 1920. (From the Company.)

Warner and Swasey Company, Turret Lathe Tools and Operator's Handbook, Turret Lathes in Railroad Shops, Turret Machines, and Fortieth Anniversary Book of the Company. Cleveland, Ohio, 1920. (From the Company.)

Warren, Webster and Company, Vacuum System of Steam Heating. Camden, New Jersey, 1920. (From the Company.)

Watuppa Water Board, Forty-sixth Annual Report, 1920. Fall River, Massachusetts. (From the Board.)

West Virginia University, Catalogue and Announcements, 1919-1920. Morgantown, West Virginia, 1920. (From the University.)

Western Wheeled Scraper Company, Catalogue No. 51, Dump Cars and Machinery. Aurora, Illinois, 1920. (From the Company.)

Whiting Foundry Equipment Company, Catalogue No. 145. Harvey, Illinois, 1920. (From the Company.)

BOOK NOTICES.

FUEL OIL IN INDUSTRY. By Stephen O. Andros, A.B., E.M. Formerly Assistant Professor of Mining Research, Engineering Experiment Station, University of Illinois. 241 pages, contents and indexes, 8vo. Chicago, The Shaw Publishing Company, 1920. $3.75.

The fuel problem has become most serious in recent years, not only from the enormous extension of power and heating plants, but from the uncertain condition in the labor relations in the great mine-fields. Investigations seem to show that the available coal supply is ample for many years, and that extensive areas are likely to be found in unexplored or partly explored parts of the world, but the getting out of the material is becoming increasingly difficult. Coal mining is a hard and dangerous occupation; the mortality and morbidity figures even under the most advanced safety systems are distressingly high. In this emergency, engineers have turned

to several methods for substitution of the old-fashioned furnace firing. One method that is attracting considerable attention is the use of powdered fuel. This materially increases the heat obtainable from a given weight of coal, simplifies the labor problem somewhat and reduces the cost of ash disposal, but the practical application is still not widely accepted. Water power—the "white coal" of the European engineers—has offered an excellent substitute for fuel, but such power is not available in all parts of the world, and its application usually involves considerable expense for plant. Incidentally, the use of such power will in many cases destroy beautiful scenery, a result which may here and there provoke active opposition, though usually the "pocket nerve" ultimately wins out.

A decided drift towards the use of fuel oil has set in lately, and it seems from the statement of the book in hand to be applicable to all important types of power and heating plants. Many forms of such plants are described, tabular information given as to relative costs of solid and liquid fuels, analytic data in considerable amount and numerous illustrations of plants, details of construction and accessory apparatus. The book presents in compact and convenient form a large amount of information of use to the power-plant and heating-plant engineer and is a timely addition to the literature of the subject. A specially interesting chapter is on "Colloidal Fuel," being an abstract from a paper read before the American Society of Mechanical Engineers, by L. W. Bates. This form of fuel is a suspension of pulverized coal in fuel oil, under conditions which prevent rapid separation of the two phases. It is produced in several forms of somewhat different consistence. It would seem that such a mixture would solve one of the objections that have been brought against the use of pulverized fuel, namely, the liability to spontaneous combustion, since the particles of coal are completely protected from air by the oil.

The literary quality of the book is not as high as it should be. Such spelling as "electrolite," which occurs several times, and the use of such terms as "benzole" indicate that carelessness of nomenclature which is too common in American works on applied science. The work will be very useful to the fuel engineer.

HENRY LEFFMANN.

CHEMICAL FRENCH. An Introduction to the Study of French Literature. By Maurice L. Dolt, Ph.D. Second edition, 8vo., 413 pages. The Chemical Publishing Company, Easton, Pa., 1920.

The first edition of this book was reviewed in this JOURNAL, and little need be added to the criticisms there made. The purpose and method of the work are excellent, and the material presented is interesting and profitable to both beginners and those who have good knowledge of the French language. Two essays have been added in the present edition, one by Le Chatelier and one by Haller. These additions have disturbed somewhat the paging of the book, and thrown the latter part of the table of contents into confusion.

The book contains a good deal of information on French grammar, including a table of the principal parts of the more important irregular

verbs and explanation of many idioms. The selections for advanced reading, consisting of original articles by distinguished chemists, represent a wide range of subject and of date, the earliest being a paper by Becquerel and one of the most recent a paper by Madame Curie.

HENRY LEFFMANN.

ELECTROMETRIC METHODS AND APPARATUS FOR DETERMINING HYDROGEN-ION CONCENTRATIONS. Catalogue 75, 39 pages, illustrations, quarto. Philadelphia, Leeds and Northrup Company, 1920.

A special interest attaches to this publication which deserves notice, namely, the explanation of the general principles of hydrogen-ion concentration and of the methods best adapted to the determination of the same. The subject is distinctly mathematical. Twenty-six pages are devoted to theory and practice and two pages of bibliography follow. Attention is called to the irregularity of the symbol used for hydrogen-ion concentration, which is often written pH, Ph or p_H. The proper form is stated to be $\not p_H$.

Inasmuch as the old methods with indicators fail to give trustworthy results in many cases, electrical methods have come in extensive use, which give the actual or effective reaction of solutions as distinguished from the total reaction. The principles upon which these measurements are made are explained in much detail and the several forms of apparatus of precision employed for the operations described. Two pages of bibliography, including about fifty representative contributions on the subject, are added.

HENRY LEFFMANN.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS. Report No. 68, A Study of the Effect of Kiln Drying on the Strength of Airplane Woods. Preprint from Fifth Annual Report. 69 pages, illustrations, plates, quarto. Washington, Government Printing Office, 1920.

The belief that kiln drying necessarily makes wood brash or "takes the life out of it" is discredited.

The report contains the results and discussion of tests on fourteen of twenty-six species tested at the Forest Products Laboratory, Madison, Wis., to find the effect of kiln drying on strength.

The chief conclusions are:

Proper kiln drying produces material fully equal to carefully air-dried stock.

Through improper kiln drying wood may have its strength properties, particularly its toughness or resistance to shock, seriously damaged without visible evidence of such damage.

The effect of a given kiln-drying process is not the same on all species.

Safe limits of temperature and relative humidity to be used in drying the several species are given.

Report No. 85, Moisture Resistant Finishes for Airplane Woods. 8 pages, illustrations, plate, quarto. Washington, Government Printing Office, 1920.

This report describes briefly a series of experiments made to determine the comparative moisture resistance of linseed oil, impregnation treatments, condensation varnishes, oil varnishes, enamels, cellulose varnishes, rubber, electroplated and sprayed metal coatings, and metal-leaf coatings when applied to wood.

All coatings except the rubber and electroplated metal coatings, which were not developed sufficiently to make them practical, admitted moisture in varying degrees. The most effective, and at the same time most practical, coating was found to be that of aluminum leaf.

Report No. 87, Effects of Nature of Cooling Surface on Radiator Performance. 13 pages, illustrations, quarto. Washington, Government Printing Office, 1920.

A discussion of the effects of roughness, smoothness and cleanness of cooling surfaces on the performance of aeronautic radiators, as shown by experimental work, with different conditions of surface on (1) heat transfer from a single brass tube and from a radiator, (2) pressure drop in an air stream in a single brass tube and in a radiator, (3) head resistance of a radiator, and (4) flow of air through a radiator. It is shown that while smooth surfaces are better than rough, the surfaces usually found in commercial radiators do not differ enough to show marked effect on performance, *provided the surfaces are kept clean.*

Report No. 88, Pressure Drop in Radiator Air Tubes. 11 pages, illustrations, plates, quarto. Washington, Government Printing Office, 1920.

A description of a method for measuring the drop in static pressure in air flowing through a radiator, and shows (1) a reason for the discrepancy noted by various observers between head resistance and drop in pressure, (2) a difference in degree of contraction of the jet in entering a circular cell and a square cell, (3) the ratio of internal frictional resistance to total head resistance for two representative types, (4) the effect of smoothness of surface on pressure gradient, and (5) the effects of supplying heat to the radiator on pressure gradient.

The fact that the pressure gradients are found to be approximately proportional to the square of the rate of flow of air appears to indicate turbulent flow, even in the short tubes of the radiator.

Report No. 91, Nomenclature for Aeronautics. 41 pages, illustrations, plates, quarto. Washington, Government Printing Office, 1920.

The nomenclature and list of symbols were approved by the Executive Committee of the Committee for publication as a technical report on April 1, 1920, on recommendation of the Subcommittee on Aerodynamics.

The purpose of this report is to secure uniformity in the official documents of the Government and, as far as possible, in technical and other commercial publications.

The stability terms were referred for special consideration to Messrs. E. B. Wilson, J. C. Hunsaker, A. F. Zahm, E. P. Warner and H. Bateman, and the power-plant terms were referred to the Sub-Committee on Power Plants for Aircraft.

Copies of the above reports may be obtained upon request from the Committee.

PUBLICATIONS RECEIVED.

Marine Engineers' Handbook, prepared by a staff of specialists. Frank Ward Sterling, Editor-in-chief. 1486 pages, illustrations, 12mo. New York, McGraw-Hill Book Company, 1920.

Fuel Oil in Industry, by Stephen O. Andros, A.B., E.M. 274 pages, illustrations, 8vo. Chicago, The Shaw Publishing Company, 1920. Price, $3.75.

Ontario Department of Mines: Twenty-ninth Annual Report. 41 pages, illustrations, 8vo. Toronto, King's Printer, 1920.

U. S. Coast and Geodetic Survey: Terrestrial Magnetism. Results of Magnetic Observations Made by the Survey in 1919 by Daniel L. Hazard. Special Publication No. 64. 27 pages, 8vo. Washington, Government Printing Office, 1920.

Bureau of Standards: Scientific Paper No. 381. An Electron Tube Transmitter of completely modulated Waves, by Lewis M. Hull, Associate Physicist. 13 pages, illustrations, 8vo. Washington, Government Printing Office, 1920. Price, 5 cents.

Bureau of Mines: Bulletin 182, Casing Troubles and Fishing Methods in Oil Wells, by Thomas Curtin. 48 pages, illustrations, plates, 8vo. Monthly Statement of Coal-mine Fatalities in the United States, May, 1920, by W. W. Adams. 8 pages, 8vo. Technical Paper 230, Determination of Molybdenum, by J. P. Bonardi and Edward P. Barrett. 35 pages, 8vo. Technical Paper 233, The Properties of Some Stoneware Clays, by H. G. Schurecht. 41 pages, diagrams, plates, 8vo. Technical Paper 238, Indicators for Carbon Dioxide and Oxygen in Air and Flue Gas, by L. H. Milligan, D. O. Crites, and W. S. Wilson. 23 pages, illustrations, plates, 8vo. Washington, Government Printing Office, 1920.

U. S. Department of Agriculture: Circular 112, Timber Depletion and the Answer. A Summary of the Report on Timber Depletion and Related Subjects, Prepared in Response to Senate Resolution 311. 16 pages, 8vo. Washington, Government Printing Office, 1920.

Application of the Spectrograph to Detection of Powerful Drugs. F. TWYMAN (*Analyst*, 1920, xlv, 303) has had much success in the detection of certain substances by means of absorption bands. Minute amounts of strychnine, cocaine, phenol, pyridin, and benzoic acid have been so detected. Twyman does not give any details as to the arrangement or operation of the apparatus.

H. L.

Altitudes in Florida. (*U. S. Geological Sur. Press Bull. No. 456*, August-September, 1920.)—The highest point in Florida whose altitude has been determined is Iron Mountain, in Polk County, which stands 325 feet above sea level. The average elevation of the State as computed by the Geological Survey is about 100 feet.

CURRENT TOPICS.

The Arrangement of Atoms in Crystals. W. LAWRENCE BRAGG. (*Phil. Mag.*, August, 1920.)—Thanks to the study of the effects of crystals upon X-rays it is now possible to state the exact arrangement of the atoms within many crystals. For example, in a crystal of sodium chloride the sodium atoms are at the corners and face-centres of a cube while the chlorine atoms are at the middle points of the cube-edges and at the centre of the cube. It is found that the relations within a crystal are geometrically represented by an assemblage of tightly packed spheres, whose centres coincide with the centres of the atoms and, further, that it is possible to assign to the sphere of the atom of any element a definite and characteristic diameter, at least within certain limits. The unit of length employed is the hundred-millionth of a centimetre.

The method of fixing the diameters of the atoms is this. Hull has studied metallic iron and has interpreted the diffraction effects of this metal upon X-rays to mean that the distance between the centres of adjacent atoms is 2.47 units. Moreover, by the same general method the arrangement of the sulphur and iron atoms in iron pyrites is known. About each atom of iron in the crystal complex let a sphere be described of 2.47 units diameter. Into this let other spheres be fitted with their centres at the centres of the sulphur atoms. The diameter which must be given to these spheres to make them touch the adjacent spheres is taken as the diameter of the sulphur atom and equals 2.05 units. By the use of the sphere-plot a certain parameter for pyrites was calculated to be .22, whereas the diffraction pattern led to the closely agreeing value of .226.

From a knowledge of the structure of zinc sulphide and of the diameter of the sulphur atom, determined as just explained, the diameter of the zinc atom is calculated to be 2.65 units. Then with the dimensions of the zinc atom as a known quantity zinc oxide is studied and the diameter of the oxygen atom is found to equal 1.30 units. The sulphur atom thus seems to be larger than the oxygen atom, and the distance from the zinc atom to the sulphur atom in zinc blende is 2.35 units. If oxygen be substituted for the sulphur, the distance from a zinc to an oxygen atom is only 1.97. This shows that the radius of the sulphur atom exceeds that of the oxygen atom by .38 units. A dimensional study of the oxides and sulphides of magnesium, calcium, silicon and barium brings out that in all these compounds the atomic radius of sulphur is longer than the corresponding dimension for oxygen.

The differences are .43, .37, .36 and .39 units, respectively. A similar investigation of halogen salts leads the author to conclude: "The replacement of fluorine by chlorine, chlorine by bromine, and bromine by iodine, increases the dimensions of the structure by an approximately constant amount."

A table of atomic diameters is given for thirty-eight elements, and these diameters are made the ordinates of a curve with the atomic numbers of the elements as abscissas. "The atomic diameters lie on a curve resembling Lothar Meyer's curve of atomic volumes. The alkali metals head each period with the greatest diameter, followed by the alkaline earths. The diameter diminishes steadily as the atomic weight is increased, reaching a minimum for the electronegative elements at the end of the period. In other words, when the atomic arrangement of compounds is taken into account, the periodic relation between the atomic volumes shown by Lothar Meyer's curve can be extended to the compounds of the atoms."

The author discusses the empirical relations he has derived in the light of the theory of atomic structure proposed by Lewis and amplified by Langmuir. According to this the small diameter of the electronegative elements is due to two such atoms in a crystal sharing electrons and of necessity being close together, while electropositive atoms do not have electrons in common with other atoms and are thus not near to them. The relative simplicity of the linking of electropositive atoms to each other indicates the reason for the crystallizing of electropositive elements in the cubic or hexagonal systems. It is reasonable, on the other hand, for the electronegative elements with some of their electrons shared by two atoms to crystallize in more complicated forms.

G. F. S.

The Dissociation of Iodine Vapor and Its Fluorescence. S. LANDAU, WARSAW, and E. STENZ. (*Phil. Mag.*, August, 1920.)—R. W. Wood has investigated the fluorescence of the vapors of sodium, mercury, and iodine. He discovered in them the remarkable property of optical resonance. The absorption spectrum of iodine vapor contains from 40,000 to 50,000 lines. When light of different wave-lengths falls upon the vapor and makes it fluoresce, the spectrum of the light emitted by the vapor is found to vary with the incident light. The investigators proposed to themselves in effect the question, "Is the complex relation between the incident and the emitted fluorescent light due to something in the structure of the molecule of iodine or does it inhere in the atom?"

It was found that an elevation of temperature has less effect than has been thought upon fluorescence. The authors observed this even at a vapor temperature of 825° C. When iodine vapor at a pressure of .25 mm. of mercury was raised to something above

1000°, fluorescence gradually disappeared. It reappeared as the vapor cooled down.

Dissociation of the iodine molecule and disappearance of fluorescence go hand in hand. For such pressure and temperature that dissociation was complete there was an entire lack of fluorescence, and of resonance spectra as well. "Thus the complicated system, corresponding to the thousands of absorption lines in the visible part of the spectrum, is not inherent in the atom, but in the molecule. The structure of the atom should be relatively simple."

A foot-note is not without interest: "During the war (and even now) it was impossible to receive regularly scientific journals at Warsaw; the authors excuse themselves for having perhaps omitted some papers concerning the question treated."

G. F. S.

Standardization of Disinfectants. A. L. WALTERS (*Amer. Jour. Pub. Health*, vol. vii, through *Lilly Scient. Bull. Ser. 1, 369*) criticises unfavorably the implicit reliance on the phenol coefficient as advocated by the Hygienic Laboratory, pointing out that different organisms react differently under standard methods of testing. He refers especially to the different action of a certain "Pine Oil Disinfectant" made according to a Hygienic Laboratory formula. Experiment showed that while according to the official method (using cultures of *B. typhosus*) this preparation has four times the power of phenol, when tested against cultures of *Staphylococcus aureus* the action was far less than that of phenol. Walters points out that the true value of a disinfectant can only be stated in terms of the organism or organisms on which it is to be used in actual practice. To state that Pine Oil Disinfectant is "an efficient liquid disinfectant" which "may be used wherever the ordinary coal-tar compounds are used" is certainly drawing erroneous conclusions from a phenol coefficient determination. In no case has the practical value of this dictum been so clearly exemplified as in the present investigation. Based on the report of Stevenson from the Hygienic Laboratory entitled "An Efficient Liquid Disinfectant," one would be led to think that "Pine Oil Disinfectant" is four to six times as effective a germicide as phenol, without any exceptions. That this is not the case has been clearly shown by the preceding experiments and contrary to the statement in the above report, Pine Oil Disinfectant cannot be satisfactorily used to replace the ordinary coal-tar compounds commonly employed as disinfectants.

The paradoxical action of pine oil in being markedly more germicidal than phenol on the typhoid bacillus and decidedly less germicidal on the staphylococcus is an interesting phenomenon deserving further study, and is apparently illustrative of specificity in disinfectants.

Unusual Minerals Mined in 1919. (*U. S. Geological Sur. Press Bulletin No. 456*, August-September, 1920.)—If the casual reader ran across the words lepidolite and amblygonite in a theological paper he might mistake them for the names of tribes of the Philistines; if he found them in a paper on fossil skeletons he might suppose they meant some kinds of armored reptiles that ranged the swamps of the Cretaceous period. A companion word, spodumene, though it ends with "mene," would mean nothing to him. Lepidolite, amblygonite, and spodumene are the names of the most abundant lithium minerals—minerals that are used as sources of the salts of lithium, one of the chemical elements. Lithium suggests a mineral water or salts used for the treatment of rheumatism. But that is another story. A large percentage of the lithium minerals mined is made into lithium for use in storage batteries of a certain type. Lithium salts and lepidolite are added to glass "batches" to reduce the viscosity of the melted glass—that is, to make it flow more freely. Lithium chloride has been used to some extent in fireworks and signal lights, to which it imparts an intense red color.

Most of the lepidolite mined in the United States is taken from a deposit near Pala, San Diego County, Calif., and most of the amblygonite is mined in South Dakota, where it occurs in masses weighing hundreds of pounds. Practically all the spodumene produced in the United States is mined in the Black Hills, in South Dakota, where it occurs in immense crystals, some of them more than 30 feet long.

Lithium minerals amounting to 6287 short tons, valued at $115,000, were produced in the United States in 1919—more than ten times as much as was produced in any year before 1916.

Deterioration of Nickel Resistors.—F. A. J. FITZGERALD and GRANT C. MOYER of the Fitzgerald Laboratories, Inc., presented at the thirty-eighth meeting of the *American Electrochemical Society* (Cleveland, September 30th–October 2nd) a communication showing that, under certain precautions, pure nickel wire is applicable as a substitute for the nichrome alloy now much used. This alloy is expensive and certain onerous conditions are attached to a license for its use. Nickel has a high thermal coefficient of electric resistance and a liability to oxidation, but it was thought that these disadvantages could be overcome. Tests, however, showed early deterioration, by the wire becoming brittle, although no marked oxidation had occurred. It was thought at first that the result was due to absorption of carbon, as the insulating material was infusorial earth and a refractory cement, both of which contained organic matter. Some of the brittle wire was tested by being heated in a current of oxygen and it was found that the emitted gas produced a precipitate of barium carbonate. The inference, however, was not correct, and details are given of experi-

ments by which it was proved that combination with sulphur is the cause of deterioration.

From the experiments it appears that:

Sulphur makes nickel brittle at low temperatures.

Nichrome wire is also affected by sulphur but less markedly.

Wire rendered brittle by sulphur can be softened by heating in a current of oxygen. Pure nickel seems to stand up well as a resistor when not exposed to contamination with sulphur.

H. L.

Ferrocerium.—ALCAN HIRCH, in a paper presented at the General Meeting of the American Electrochemical Society, in April, 1920, presents interesting data in regard to the pyrophoric alloys of cerium and iron. At first these were merely matters of curiosity, but their manufacture has now grown to be an important industry. During the recent war, pyrophoric lighters formed part of the equipment of every soldier, particularly the form termed "fuse" or "wind" lighter. The "iron match" as Hirch calls it, is steadily replacing the wooden match, among the advantages of the former being its general safety and the saving in bulk.

The cerium alloy depends on the residues from the gas-mantle industry. Formerly these residues were considered waste products, but the entire output is now utilized in the manufacture of flaming ores, special glass, and the pyrophoric alloys. A brief outline is given of the methods of making the alloys, the author stating that the process, which is electrolytic, is one of the most peculiar known. The starting point is a mass of metals of the cerium group. This is soft but tough, can be cut by a strong knife and is not pyrophoric. This mass is melted and alloyed with iron, the latter forming about one-third the mixture. Other alloys can be prepared which give flame or a shower of sparks. Magnesium and zinc are used for special purposes. The pyrophoric quality depends on the brittleness of the alloy and its low kindling point. Metals of the cerium group have a very high affinity for oxygen. The three properties of low melting point, high affinity for oxygen and nitrogen, and high density seem to indicate valuable applications for deoxidizing molten metals. The author gives some data from experiments in this line.

H. L.

PRESS OF
J. B. LIPPINCOTT COMPANY
PHILADELPHIA